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Contents

J. Rubb. Res. Inst.
Malaya 17 (1961)

THE EFFECT OF MAGNESIUM LIMESTONE AND OTHER FERTILISERS ON A MATURE PLANTING OF HEVEA BRASILIENSIS 31

J. Bolton and V. M. Shorrocks

REDUCTION OF VIABLE BACTERIA IN LATEX BY ULTRA-VIOLET IRRADIATION 40

S. Sethu

INVESTIGATIONS INTO THE RELATIONSHIP BETWEEN STOCK AND SCION IN BUDDED TREES OF HEVEA BRASILIENSIS 46

B. R. Buttery

See back cover for details of subscription, previous issues and indexes. Publication is irregular, the volume being completed at the end of a period of two years. Volume 17 will be completed at the end of 1962.

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VOLUME 17 PART 2

The Effect of Magnesium Limestone and Other Fertilisers on a Mature Planting of Hevea brasiliensis

J. BOLTON and V. M. SHORROCKS

Growth and yield responses were measured following applications of magnesium limestone, potassium chloride and a combined application of ammonium sulphate and rock phosphate to an area of mature rubber showing leaf symptoms of magnesium deficiency. Significant positive effects of magnesium limestone were evident on growth during the first and each subsequent year and on yield during the fifth and each subsequent year after the first of three biennial fertiliser applications. The effects increased with time until the experiment was terminated four years after the final application of fertilisers.

Leaf, latex and soil analyses, carried out four years after the final application of fertilisers, are discussed briefly in relation to the growth and yield responses.

Leaf symptoms associated with magnesium deficiency have been observed over large areas of mature *Hevea* both in Malaya and other countries. The characteristic interveinal chlorosis, described and illustrated by BOLLE-JONES (1956), has been reported on many different clones and soil types, yet little information on the effects of magnesium applications on growth and yield of mature trees has been published except very briefly in Annual Reports (RUBBER RESEARCH INSTITUTE OF MALAYA, 1958–60; RUBBER RESEARCH INSTITUTE OF CEYLON, 1955; INSTITUT DES RECHERCHES SUR LE CAOUTCHOUC EN INDOCHINE, 1958).

This paper is a short account of an experiment designed primarily to test the effectiveness of magnesium limestone on growth and yield of trees showing leaf symptoms of magnesium deficiency. At the time when the experiment started (1950) these symptoms were being observed more and more frequently in Malaya, particularly on replanted areas, but no definite effects on leaf colour of applications of magnesium in any form had been recorded. It was suggested that potassium might be an additional complicating factor in the experimental area and consequently potassium chloride was included as a separate treatment. High and low levels of a mixture of nitrogen and phosphate fertilisers—to which the main response was expected—formed the third set of treatments.

EXPERIMENTAL METHOD

The field chosen for the experiment was a young mature replanted area budded in 1938 with Pilmoor D65 and tapped for the first time in 1947. The fertiliser programme during immaturity is not known, but an NPK mixture was probably applied regularly up to 1941 (all the estate records were lost during the Japanese occupation). After the war the secondary vegetation was cleared and an application of 3 lb per tree of an NPK mixture given at the time of opening in 1947. The experiment commenced in December 1950 and the fertiliser treatments, shown in *Table 1*, were applied three times, in 1950–51, 1953 and 1955. Magnesium limestone was applied one month later than the other fertilisers to avoid any possible loss of ammonia from the ammonium sulphate. The design was a 3 × 3 × 3 factorial giving twenty-seven treatments in three blocks each containing nine plots.

COMMUNICATION 340

TABLE 1. DETAILS OF THE FERTILISER TREATMENTS, LB PER TREE

Applied in December—January 1950—51, March 1953, March 1955.

Type of fertiliser	Level of application		
	0	*1*	*2*
Magnesium limestone *(mg)*	0	1½	3
Potassium chloride *(k)*	0	½	1
Ammonium sulphate and *(np)* Rock phosphate	0	2½	2½
	0	1½	3

Girth measurements were made at a fixed height of 60 inches at the beginning of the experiment (December 1950) and then annually up to 1959. Yields were recorded monthly from 1951 to 1959 using the cup coagulation technique described by OWEN, WESTGARTH AND IYER (1957). Throughout the experiment, the trees were tapped alternate daily (S/2.d/2.100%).

The soil in the experimental area was a freely drained, yellow brown clay loam of a uniform texture to a depth of 60 inches, except for a thin quartz vein present at about 36 inches. The parent material is not known but is probably schist or shale. Mechanical and chemical analyses of profile samples are summarised in *Table 2*.

Soil, leaf and latex sampling was carried out at the conclusion of the experiment in 1959, four years after the final application of fertilisers. Soil samples (0 – 12 inches) were collected and analysed by the method described by BOLTON (1961). For the leaf samples, two mature whorls from spurs of limited growth in the shade of the canopy, were chosen from each tree sampled, and the four basal leaves on both whorls collected. In each plot six trees were selected at random for sampling, and all the leaves collected from one plot were bulked to form one sample for analysis. Latex samples were collected, after latex flow had stopped, from the same six trees.

The magnesium, potassium, nitrogen and phosphorus contents of both leaves and latex, and also the calcium and manganese contents of the leaves were determined. The results of leaf analysis (*Table 6*) are expressed on a dry weight basis, and the latex analysis results (*Table 7*) as a percentage on the serum content of the latex.

RESULTS

Tables of results shown in the following sections give only the main effects of the treatments. In most cases, interactions were not important or significant but those which have occurred are described in the text.

TABLE 2. SOIL ANALYSES OF PROFILE SAMPLES TAKEN FROM THE CONTROL PLOT

Depth, inches	Sand		Silt	Clay	pH	Exchangeable (m-equiv./100g)			Available P_2O_5, p.p.m.
	Coarse	Fine				K	Mg	Ca	
0— 3	30.1	12.1	9.0	46.6	4.97	0.097	0.090	0.090	16
3—12	24.8	14.5	11.9	48.9	5.03	0.031	0.041	0.045	6
12—24	26.5	12.6	5.9	57.0	5.06	0.018	0.025	0.060	5
24—28	24.6	12.4	4.5	59.4	5.14	0.015	0.033	0.040	4

TABLE 3. THE EFFECT OF FERTILISER TREATMENTS ON ANNUAL TREE GROWTH TOGETHER WITH INITIAL AND FINAL GIRTH MEASUREMENTS (INCHES)

Treatment	Initial girth, Dec. 1950	Dec.-Mar. 50—52	Mar.-Mar. 52—53	Mar.-Mar. 53—54	Mar.-Mar. 54—55	Mar.-Mar. 55—56	Mar.-Mar. 56—57	Mar.-Mar. 57--58	Mar.-Mar. 58—59	Total Dec.-Mar. 50—59	Final girth, Mar. 1959
Control, mg_0	24.57	0.873	0.649	0.377	0.560	0.517	0.587	0.452	0.346	4.361	28.93
mg_1	25.47	1.164*	0.787	0.400	0.682	0.921*	0.744*	0.929*	0.418	6.045*	31.52*
mg_2	24.83	1.156*	0.883*	0.443	0.725	1.033*	0.796*	1.068*	0.501*	6.605*	31.43*
Control, k_0	24.89	1.030	0.743	0.402	0.629	0.840	0.700	0.796	0.403	5.543	30.43
k_1	24.98	1.037	0.780	0.396	0.678	0.802	0.685	0.807	0.422	5.607	30.59
k_2	24.99	1.127	0.796	0.422	0.661	0.829	0.742	0.846	0.438	5.861	30.85
Control, n_0p_0	25.49	0.988	0.757	0.334	0.592	0.763	0.603	0.783	0.394	5.214	30.70
n_1p_1	24.60	1.091	0.729	0.414	0.646	0.822	0.728	0.839	0.418	5.687	30.29
n_1p_2	24.80	1.114	0.833	0.471*	0.729	0.887*	0.796*	0.827	0.429	6.086*	30.89
s.e. ±	—	0.065	0.050	0.033	0.065	0.040	0.051	0.048	0.045	0.248	0.53
l.s.d. (P=0.05)	—	0.196	0.149	0.100	0.196	0.120	0.154	0.144	0.135	0.744	1.59

* denotes significant difference from control.

Growth Measurements

The annual girth increments are given in *Table 3* together with the initial and final girth measurements. Magnesium limestone increased the growth rate during the first year after application and in each subsequent year, all effects except one being statistically significant. During the first year, the lower level of application was just as effective as the higher level but the effect of the latter increased until in the final year the magnesium effects were linear. Over the whole period of the experiment, in which there were three applications of the fertiliser, growth was increased 39% at the lower level of application of 4½ lb (3 × 1½ lb) per tree and 51% at the higher level of 9 lb (3 × 3 lb) per tree. These large increases show that for mature rubber as well as for young seedlings (BOLLE-JONES, 1954) growth can be severely retarded by magnesium deficiency. The increasing response to each level of magnesium limestone during the final year suggests that there would have been a further response to higher levels of magnesium limestone than were applied.

Potassium chloride had no effect on growth either over the whole period or in any individual year.

The combined ammonium sulphate and rock phosphate applications (*np*) increased growth in the third year and in two subsequent years. At the end of the experiment, the overall effect of the lower level of *np* was an increase in growth of 9% and of the higher level of *np* an increase of 17%. The larger response to the higher level of *np* suggests that the main response was to the phosphate,

TABLE 4. THE EFFECT OF FERTILISER TREATMENTS ON YIELD, GRAMS PER TREE PER TAPPING

Each figure is the mean of 12 tappings carried out monthly from February of one year to January of the next

Treatment	1951 - 52	52 - 53	53 - 54	54 - 55	55 - 56	56 - 57	57 - 58	58 - 59	Mean 1951 - 1959
Control, mg_0	29.4	32.8	24.5	20.4	19.2	21.5	20.6	21.6	23.7
mg_1	29.6	34.1	26.1	20.4	23.5*	24.5*	23.6*	23.9*	25.7
mg_2	29.2	32.7	25.7	20.5	21.2	23.3	24.1*	24.6*	25.2
Control, k_0	29.2	33.1	26.0	20.6	21.3	23.3	21.6	22.2	24.6
k_1	29.6	33.6	26.2	20.4	20.8	23.1	24.4	24.0	25.3
k_2	29.3	33.0	24.2	20.3	21.7	22.9	22.2	23.9	24.7
Control, n_0p_0	29.1	32.5	25.3	20.3	19.8	22.8	22.2	23.1	24.4
n_1p_1	30.2	33.9	25.1	21.4	21.1	22.5	23.0	23.7	25.1
n_1p_2	28.8	33.3	26.0	19.5	23.0*	23.9	23.1	23.4	25.1
s.e. ±	0.60	0.57	0.79	0.60	0.95	0.79	0.57	0.64	
l.s.d. (P=0.05)	1.81	1.70	2.38	1.81	2.83	2.38	1.70	1.97	

* denotes significant difference from control.

since the same level of ammonium sulphate (see *Table 1*) was applied to the plots receiving both the high and low levels of rock phosphate.

An interesting observation in 1957 and thereafter was that the time of wintering was affected by the magnesium applications, the control plots wintering earlier than the treated plots. No such effect was noticed in the earlier stages (1952) although improvement in leaf colour could be easily seen. The effect on wintering is probably associated with the fact that magnesium deficiency symptoms are usually more prevalent in the months before the annual leaf fall.

Yield Measurements

Previous investigations (OWEN, WESTGARTH AND IYER, 1957) have shown that in *Hevea*, the response in yield to fertiliser applications is seldom immediate and usually follows a response in terms of growth. This experiment follows the same pattern and significant increases in yield due to the magnesium limestone were not recorded until the fifth year (*Table 4*). The yield responses increased with time until in the final year the lower level of magnesium limestone increased yields by 11%, the higher level by 14%. Comparison of these figures with the linear effects on growth in the final year suggests that the full effects of the magnesium limestone had not become apparent even at the conclusion of the experiment.

No definite response to potassium was found in any year or over the whole period.

The nitrogen-phosphate mixture increased yields significantly in only one year (1955–56), two years after a growth response had been measured.

The reduction in yield after the third year coincided with a change from virgin to first renewed bark which had been tapped full-spiral, fourth daily, for two years before the experiment started.

Soil Analysis

The plot-by-plot soil analyses (*Table 5*) have been fully discussed in a previous paper (BOLTON, 1961) together with the results of

TABLE 5. THE EFFECT OF FERTILISER TREATMENTS ON SOIL COMPOSITION (0—12 INCHES)
Date of sampling: March 1959

Treatment	pH	Exchangeable (m—equiv./100g)			p.p.m. available P_2O_5
		K	Mg	Ca	
Control, mg_0	4.97	0.077	0.066	0.104	36.5
mg_1	4.99	0.090	0.093	0.104	26.8
mg_2	4.92	0.099	0.107*	0.109	57.8
Control k_0	4.97	0.077	0.089	0.097	38.5
k_1	4.94	0.097	0.091	0.105	32.0
k_2	4.98	0.092	0.085	0.114	53.6
Control, n_0p_0	5.05	0.095	0.090	0.101	13.8
n_1p_1	4.92*	0.081	0.081	0.106	20.2
n_1p_2	4.92*	0.091	0.095	0.108	87.0*
s.e. ±	0.03	0.012	0.011	0.007	10.6
l.s.d. (P=0.05)	0.09	0.037	0.034	0.021	31.0

* denotes significant difference from control.

measurements in other experiments. Briefly, there were significant increases in exchangeable magnesium from the magnesium limestone, available P_2O_5 from the rock phosphate, and depressions in pH due to the ammonium sulphate. There was also an indication of increased exchangeable potassium from potassium chloride (significant at P = 0.10).

Leaf Analysis

Applications of magnesium limestone (*mg*) resulted in a significant increase in the leaf magnesium content, and in significant reductions in the leaf content of potassium, nitrogen, phosphorus and manganese (*Table 6*). Despite the high calcium content (21% Ca) of the fertiliser, no effect on the leaf calcium was observed.

The maximal mean concentration of leaf magnesium observed after application of *mg* was less than the average of 0.26% observed on clones PB 86 and RRIM 501 by SHORROCKS (1961a). The nature of the growth response (*Table 3*) indicates that a greater response would have been obtained to further applications of *mg*. Thus it would appear that the optimum level for leaf magnesium was not attained in the present experiment.

The negative effect of magnesium on leaf potassium was significant when potassium chloride (*k*) was also applied, but was not significant in the absence of applied *k*.

The striking reduction in leaf manganese caused by applications of *mg* is in accord with the work of BOLLE-JONES (1957), who reported a similar effect in a sand culture experiment. Soil analysis shows that the reduction in leaf manganese cannot be attributed to an increase in soil pH (*Table 5*).

The combined application of ammonium sulphate and rock phosphate (*np*) resulted in a small but significant reduction in the leaf magnesium content, (*Table 6*), an effect which

TABLE 6. THE EFFECT OF FERTILISER TREATMENTS ON THE CONCENTRATION OF NUTRIENTS IN DRY LAMINA

Date of sampling: May 1959

Treatment	% Mg	% K	% N	% P	% Ca	p.p.m. Mn
Control, mg_0	0.13	1.20	3.26	0.21	0.70	188
mg_1	0.19*	1.18	2.95*	0.21	0.66	156
mg_2	0.22*	1.11*	2.92*	0.19*	0.68	98*
Control, k_0	0.18	1.04	3.04	0.21	0.70	169
k_1	0.18	1.23*	3.05	0.20	0.65	142
k_2	0.19	1.21*	3.05	0.20	0.69	131
Control, n_0p_0	0.20	1.25	3.05	0.18	0.61	143
n_1p_1	0.18	1.12*	3.04	0.21*	0.71*	154
n_0p_2	0.17*	1.11*	3.05	0.22*	0.71*	145
s.e. ±	0.007	0.032	0.084	0.005	0.018	23.1
l.s.d. (P=0.05)	0.021	0.095	0.251	0.016	0.053	68.6

*denotes significant difference from control.

was only apparent when *mg* was also applied. The maximal mean leaf magnesium content was obtained when *np* was not applied.

The application of *np* caused a significant reduction in the leaf potassium and significant increases in the leaf phosphorus and calcium, findings which are in agreement with the work of SHORROCKS (1961b) on *Hevea*, who reported that ammonium sulphate depressed leaf potassium, and that rock phosphate applications increased leaf phosphorus and calcium.

The leaf potassium content was significantly increased by the application of potassium chloride (*k*), but no other significant effects of *k* were observed on the leaf nutrient composition.

Latex Analysis

The application of magnesium limestone resulted in significant increases in the latex magnesium and phosphorus (*Table 7*). There were indications that the serum content of the latex was reduced by application of *mg*, but this reduction was not of sufficient magnitude to affect markedly the estimation of the increases in the latex magnesium and phosphorus when expressed as a percentage of the serum content.

The latex phosphorus content was significantly increased by the application of *np*, but no other significant effects on the latex nutrient composition were observed.

DISCUSSION

The most important result of the experiment has been the significant increase in tree growth and yield of rubber coupled with the amelioration of the leaf symptoms of magnesium deficiency, following applications of magnesium limestone. The steady development of the yield response over a period of several years confirms other previous observations—(OWEN, WESTGARTH AND IYER, 1957; HAINES AND GUEST, 1936; CHAPMAN, 1941) that it is difficult to influence the yield of *Hevea* in a short period by the application of fertilisers. The usual sequence of improved

TABLE 7. THE EFFECT OF FERTILISER TREATMENTS ON THE CONCENTRATION OF NUTRIENTS IN LATEX (EXPRESSED AS % WEIGHT ON SERUM) AND ON THE SERUM CONTENT

Date of sampling: May 1959

Treatment	% Mg	% K	% N	% P	% Serum	$\frac{Mg}{P}$
Control, mg_0	0.024	0.29	0.32	0.067	66.9	0.34
mg_1	0.034*	0.30	0.32	0.073	65.9	0.47*
mg_2	0.034	0.31	0.33	0.079*	64.7	0.43
Control, k_0	0.028	0.30	0.31	0.072	66.4	0.37
k_1	0.031	0.30	0.33	0.072	65.6	0.43
k_2	0.032	0.30	0.33	0.074	65.6	0.43
Control, $n_0 p_0$	0.028	0.30	0.31	0.069	65.8	0.40
$n_1 p_1$	0.032	0.29	0.33	0.072	66.3	0.43
$n_1 p_2$	0.031	0.30	0.33	0.078*	65.4	0.40
s.e. ±	0.0024	0.008	0.012	0.0025	0.75	0.030
l.s.d. (P=0.05)	0.0072	0.023	0.038	0.0075	2.27	0.089

*denotes significant difference from control.

TABLE 8. PERCENTAGE INCREASES IN GIRTH AND YIELD FROM MAGNESIUM LIMESTONE OVER THE WHOLE PERIOD OF THE EXPERIMENT (CONTROL=100)

Treatment	Girth			Yield		
	Initial	Final	Increase	Initial	Final	Increase
Control, mg_0	100	100	—	100	100	—
mg_1	104	109	5	101	111	10
mg_2	101	109	8	99	114	15

canopy preceding improved growth which is followed later by an increase in yield has been observed, although over the eight years of the experiment there has been a greater percentage increase in yield than in tree girth (i.e., the increased yield cannot be explained solely by an increase in the length of the tapping cut (*Table 8*)). It follows therefore that the application of fertilisers to *Hevea* is a long term investment and that it may be several years before the benefits become fully apparent. However, such returns as have been found in this experiment would be highly profitable on present day costs.

The experiment emphasises too the importance of magnesium as a major nutrient for *Hevea*, worthy of equal consideration with nitrogen, phosphate and potassium. Growth and yield responses have been found comparable with the largest responses to the major elements already measured in other experiments, although it should be emphasised that this was an area showing deficiency symptoms. Some clones (e.g. PB 86) show these symptoms much more readily than others (e.g. Gl 1) and it is quite possible, indeed probable, that there are clone-fertiliser interactions, some clones requiring higher levels of magnesium in the soil than others.

As already stated, the effects of magnesium applications on growth, particularly in the final year, indicate that increased amounts of magnesium limestone would have given greater responses. It seems, therefore, that the maximal leaf magnesium content of 0.23%, and the maximal soil exchangeable magnesium content of 0.107 m-equiv./100 g measured in this experiment are sub-optimal for growth, assuming, of course, that the exchangeable soil magnesium content reflects the magnesium available to the tree.

The depressive effect of magnesium limestone on the leaf manganese content suggests that manganese deficiency could be induced by the excessive application of magnesium limestone, especially when the manganese status of the trees is low.

Potassium applications, although increasing the potassium content of the leaves, resulted in no significant increase in growth or yield—suggesting that the levels of potassium in the leaves and soil were adequate. It is surprising that under these conditions of magnesium deficiency, no effects of potassium applications on leaf magnesium were recorded. In previous investigations SHORROCKS (1961b) reported a depressive effect of potassium on leaf magnesium.

The nitrogen-phosphate treatment resulted in small increases in growth and yield. It is however difficult to segregate the effects of these two fertilisers and to relate the responses to the changes in leaf and latex nutrient composition.

In view of the depressive effect of applied *np* and the previously reported depressive effect of applied potassium on the leaf magnesium content, further work seems to be

required on the correction of magnesium deficiency, particularly with regard to the use of mixed N P K Mg fertilisers, in which the proportion of magnesium is relatively low (mixtures in current use in Malaya normally contain less than 10% of magnesium sulphate —equivalent to 2.6% MgO).

Magnesium limestone applications increased both the magnesium content of the latex and the latex Mg: P ratio. The latter effect was however minimised by the concomitant increase in the latex phosphorus content. The Mg: P ratio has been related, under certain conditions, to stability of latex on the tapping cut and yield (d'Auzac 1960), whereby an increase in the ratio is associated with pre-coagulation and a reduced yield. No such effects were observed in this experiment on magnesium deficient trees.

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Reduction of Viable Bacteria in Latex by Ultra-Violet Irradiation

S. SETHU

Bactericidal effects in natural rubber latex (ammoniated) resulting from ultra-violet irradiation were investigated quantitatively. Two systems of irradiation were examined; firstly a jacket tube device in which either flowing or stationary latex could be irradiated; secondly a jacket tube device in which a very thin film of latex was exposed to radiation. The first system was shown to be impracticable under the conditions studied. The second system gave a satisfactory and consistent reduction in viable bacterial population. At the intensities of u.v. radiation studied, no adverse effect on rubber properties was detected. The cost of operation of bactericidal irradiation of latex is shown to be rather high.

The importance of bactericidal effects in latex preservation and shipment overseas are well established (TAYSUM, 1957). In all cases where ammonia is present at low concentrations, bactericidal measures are of prime importance in preservation. Lower V.F.A., lower KOH number and high mechanical stability are some of the effects expected to result from sterilising the latex (GRAHAM AND TAYSUM).

It has been known for a long time that ultra-violet (u.v.) radiation can kill or at least inhibit the reproduction of micro-organisms, and investigations have established that wavelengths between about 2,500 and 2,700 Ångstrom units (Å) are the most effective (WYCKOFF, 1932). The lethal action of u.v. radiation has been found to have a temperature coefficient of approximately 1.1 (BAYNE-JONES AND VAN DER LINGEN, 1923). Ultra-violet irradiation has been successfully adopted to reduce the viable bacterial population of blood plasma (VALLET, 1957).

Ultra-violet irradiation of field and concentrated latices gave promising reductions in viable bacterial population in small scale trials using a Hanovia 9-watt spiral lamp (Model 18) and a G.E.C. 30-watt germicidal lamp to irradiate the latex. When field latex (ammoniated to 0.3%) and latex concentrate (ammoniated to 0.7%) were exposed to u.v. irradiation by immersing the u.v. lamp in latex about 2 mm deep in a beaker for 30 seconds, the following percentage reductions in viable bacteria were obtained (TAYSUM, 1956a):

Field latex	99%
Latex concentrate	90%

In view of these results further investigations which are described in this paper were initiated, the aims being: to investigate different types of irradiation systems suitable for commercial application; to see whether u.v. irradiation has an adverse effect on rubber; to estimate the cost and value of irradiation. Complete sterilisation of latex was not attempted.

EXPERIMENTAL METHODS

1. *Apparatus and Procedure for Irradiation*

(a) *Flow type apparatus.* The u.v. tube, either a Hanovia 30 watt (2537Å) straight-tube lamp with ozone reducing filter (Model 13A) or a G.E.C. 30 watt (2537Å) germicidal lamp, was fitted with an aluminium jacket, the annulus between the tube and the jacket (3 to 6 mm) being filled with field latex. The Rubber Research Institute Experiment Station

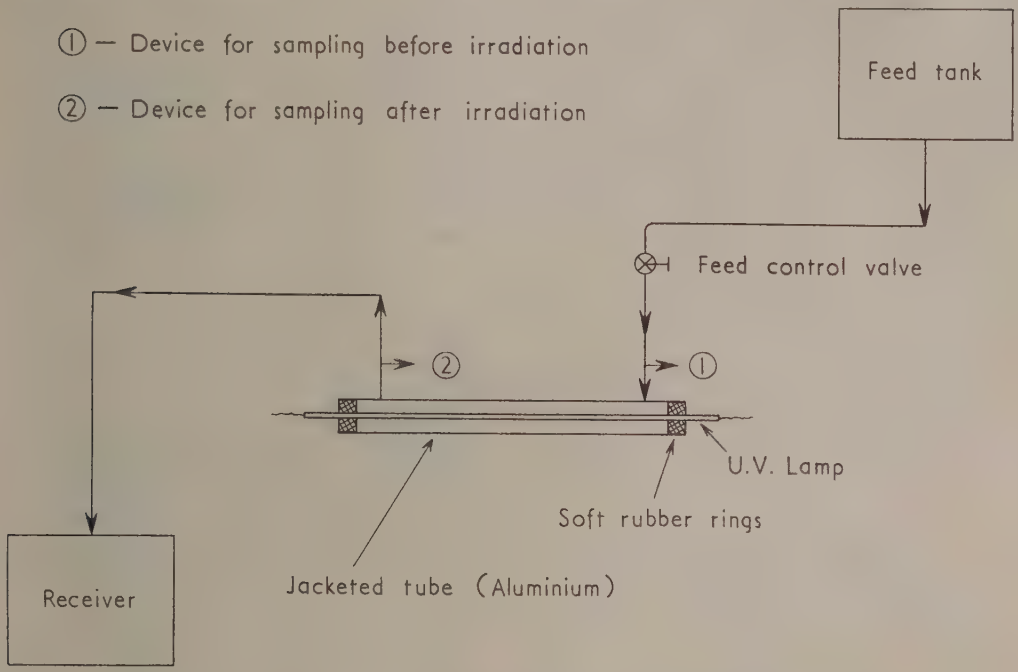

Figure 1. Jacket tube (flow type) apparatus for the irradiation of latex.

factory bulk from daily collection was used in all cases. For the study of short periods of irradiation (1 to 70 seconds) latex flowed through the apparatus continuously from a feed (head) tank (*Figure 1*). The procedure of the experiment was briefly as follows. The floor and the plant were washed with 5% chlorinated tri-sodium phosphate to ensure initial sterilisation. The u.v. lamp and the jacket tube were fixed in position using soft rubber rings. The latex was then poured into the feed tank and the flow rate of latex through the annulus was adjusted to give a pre-determined time of contact. Samples were taken before and after u.v. irradiation for bacterial counts.

For longer periods of irradiation (10 to 75 minutes) the latex was treated in batches, the latex being poured in to fill the annulus and allowed to remain stationary during irradiation.

(b) *Film type apparatus.* The second apparatus enabled a very thin film about (0.1 mm) to be exposed to radiation. It consisted of a jacket tube (either glass or aluminium) 2.5 in. in diameter with soft annular rubber rings (external diameter 2.5 in., internal diameter 1.625 in.) attached at the ends. The u.v. lamp (either Hanovia or G.E.C.) was placed in the middle, leaving a considerable gap between the lamp and the rubber rings.

The experimental procedure was as follows. The jacket tube was initially sterilised by the u.v. lamp for about 15 minutes. Twenty-five c.c. of the latex were then pipetted in. The jacket tube was then rotated fairly rapidly (about 20 r.p.m.) by hand, so that a thin film of latex was formed around the inner surface of the jacket tube. The thin film was then exposed to u.v. radiation for one minute. Samples of latex were taken immediately

TABLE 1. REDUCTION IN VIABLE BACTERIAL POPULATION OBTAINED WITH ROTATING TUBE SYSTEM

(Time of exposure to irradiation one minute)

Hanovia (30 Watt) straight tube lamp

Expt No.	Total number of viable bacteria per ml		Percentage reduction in viable bacteria
	Before irradiation	After irradiation	
1	3.3×10^4	1.3×10^4	60.6
2	2.9×10^4	3.5×10^3	88.0
3	1.6×10^5	4.2×10^3	97.5
4	2.6×10^5	6.0×10^4	77.0
5	2.9×10^5	1.1×10^4	99.7
6	1.2×10^6	1.0×10^5	91.7
7	1.4×10^6	5.7×10^5	59.3
8	2.0×10^6	1.5×10^5	92.5
9	9.2×10^6	7.6×10^5	91.7
10	1.6×10^7	1.1×10^6	93.1
11	2.8×10^7	6.3×10^6	77.5
12	7.1×10^5	3.3×10^4	95.5
13	1.0×10^7	1.0×10^6	90.0
14	1.0×10^5	4.0×10^3	96.0
15	9.1×10^5	1.2×10^4	98.7
16	7.0×10^4	2.2×10^3	96.9
17	1.4×10^5	9.2×10^3	93.5
18	5.6×10^5	2.9×10^4	94.8

G.E.C. (30 Watt) germicidal lamp

1	1.8×10^3	nil	100.0
2	2.1×10^4	6.8×10^3	67.6
3	2.0×10^5	8.6×10^4	57.0
4	2.9×10^5	3.1×10^4	89.3
5	5.0×10^5	1.1×10^5	78.0
6	5.6×10^5	2.4×10^4	95.7
7	4.7×10^5	9.0×10^3	98.1
8	4.2×10^4	9.5×10^3	77.4

before and after irradiation for bacterial counts.

In all the above experiments, sterile glass test tubes capped with a sterile non-absorbent plug of cotton wool and containing a trace of sterile isotonic saline (0.85% w/w NaCl) were used for sampling purposes. A modified Kligler's iron agar medium was used for estimating the viable bacterial population of latex samples (TAYSUM, 1956b).

2. *Estimation of the Effect of u.v. Irradiation on the Ageing Properties of Rubber*

Total solids (T.S.) films and coagulated rubber samples were prepared from untreated and irradiated latices and the 'D_{10} plasticity' values measured before and after 72 hours oven ageing at 100°C. The irradiated latices were obtained from rotating tube (film type) irradiation experiments.

RESULTS AND CONCLUSIONS

Flow Type Apparatus

Out of 28 samples irradiated with a Hanovia straight tube lamp, using an exposure time of 1 to 2 seconds and an annulus width of 3 mm,

7 gave no reduction in viable bacteria,
8 gave 10 to 50% reduction,
3 gave 50 to 70% reduction,
3 gave 70 to 90% reduction,
7 gave 90 to 97% reduction.

Out of 40 samples irradiated with a G.E.C. germicidal lamp, using 20 to 70 seconds exposure time and an annulus width of 6mm,

8 gave no reduction in viable bacteria and
32 gave 0.6 to 32% reduction in viable bacteria.

Thus the results obtained with flow conditions are inconsistent and no definite conclusion can be derived. However, it can be generally stated that in the majority of the cases the percentage reductions in bacterial population obtained are low.

Flow Type Apparatus. Latex Stationary

Of the 3 samples irradiated with a Hanovia straight tube lamp, using an annulus width of 3 mm,

1 gave 94% reduction in viable bacteria with 10 minutes exposure time,
1 gave 95% reduction in viable bacteria with 30 minutes exposure time,
1 gave 99.5% reduction in viable bacteria with 75 minutes exposure time.

In all the above cases a film of rubber was formed on the surface of the u.v. tube. This is considered to be undesirable.

Film Type Apparatus (Rotating Tube)

Out of 18 samples irradiated with a Hanovia straight tube lamp, and exposed for 1 minute,

2 gave 50 to 70% reduction in viable bacteria,
3 gave 70 to 90% reduction,
13 gave 90 to 98.5% reduction.

Out of 8 samples irradiated with G.E.C. germicidal lamp, and exposed for 1 minute,

2 gave 50 to 70% reduction in viable bacteria,
3 gave 70 to 90% reduction,
3 gave 90 to 100% reduction.

As the percentage reductions in bacterial population obtained are high and consistent, it is concluded that the rotating tube type of irradiation is more satisfactory than the others.

Detailed results of both Hanovia and G.E.C. lamp experiments are given in *Table 1*.

The results are given in terms of a numerical bacterial count without error estimate but their application for the purpose of this paper is only to show the trend in the reduction of bacterial population and its consistency.

TABLE 2. AGEING OF RUBBER FROM LATICES OBTAINED BEFORE AND AFTER IRRADIATION,* USING A ROTATING TUBE APPARATUS

Expt No	Designation	Williams Plasticity				Remarks
		Normal		Oven : 72 hrs T = 100°c		
		D_{10}	Recovery	D_{10}	Recovery	
1	before irradiation	2.76	3.35	2.98	4.67	Total solids film
	after irradiation	2.91	3.62	2.82	4.84	
	before irradiation	2.91	3.65	1.41	1.79	Coagulated rubber
	after irradiation	2.65	3.40	1.38	1.64	
2	before irradiation	3.30	4.92	3.15	5.24	Total solids film
	after irradiation	3.12	4.69	2.95	4.93	
	before irradiation	2.58	5.41	2.08	2.57	Coagulated rubber
	after irradiation	3.38	5.21	2.48	3.29	
3	before irradiation	2.75	3.50	2.72	4.13	Total solids film
	after irradiation	2.97	3.91	2.84	4.80	
	before irradiation	2.90	3.81	2.25	2.99	Coagulated rubber
	after irradiation	3.25	4.36	2.67	3.98	

*Reduction in bacterial population after irradiation was approx. 95%

Ageing

The results obtained for ageing of rubber from untreated and irradiated latices are given in *Table 2*. There is no significant difference in ageing properties between the two rubbers.

COST ESTIMATION

The cost estimation is based on the rotating tube irradiation system in which the latex was exposed to u.v. radiation in a form of thin film, as it gave a satisfactory and consistent reduction in viable bacterial population.

Taking 25 c.c. per minute of 36% d.r.c. field latex (or 9 gm of rubber per minute) as the throughput per tube, the power required for a 30 watt lamp is 0.025 kWh per pound of rubber. Assuming the cost of power as 7 cents (Malayan) per kWh, the cost of power required to operate the unit is 0.175 cents per pound of rubber. Assuming that a lamp has a normal life of 3,000 hours (Hanovia Ltd, 1957) and an initial cost of $30, the depreciation charge is 0.84 cent per pound of rubber. Thus the total cost including power and depreciation for lamps, but excluding the cost of labour and the capital depreciation for the plant, is 1.0 cent per pound of rubber.

A plant with 100 gallons per hour throughput would require 303 u.v. lamp units and the capital cost of lamps would be approximately $9,000 (Malayan).

DISCUSSION

Inconsistent reductions in viable bacteria were obtained using the jacket tube apparatus to give a short time of contact under flow conditions. Longer times of exposure with the latex remaining stationary gave a good bacterial kill, but unfortunately under these conditions a film of rubber formed on the surface of the tube, probably due to heating of the latex.

The exposure of the latex in the form of a very thin film, e.g. 0.1 mm thickness, overcame this difficulty and good reductions were obtained with an exposure of one minute. No differences in ageing properties were observed between the rubber samples from untreated and irradiated latex.

The economics of the process are, however, less encouraging. The total cost of power, and the depreciation charge for the lamps is 1.0 cent (Malayan) per pound of rubber. Although the degree of bacterial kill obtained would be valuable as a means of improving preservation, the cost as estimated is excessive.

The project thus appears uneconomic at present, unless a cheaper source of u.v. radiation can be obtained. An alternative method, which might prove more economic and could be considered for further investigation, is to employ higher intensity u.v. sources permitting the use of thicker films.

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VOLUME 17. PART 2

Investigations Into the Relationship Between Stock and Scion in Budded Trees of Hevea brasiliensis

B. R. BUTTERY

The results of seven long-term investigations into the relationship between clonal scions and illegitimate seedling stocks are reported and discussed. Yield and trunk girth are the main factors considered. In general, scion effects are more clearly established and are of greater magnitude than stock effects; this phenomenon is discussed in relation to the reported results of stock-scion experiments in temperate tree crops.

This paper will consider the results of seven long term stock-scion experiments which were started in the 1930's and continued to be recorded until recently. All of these experiments were at the R.R.I.M. Experiment Station at Sungei Buloh, except for one on a coastal estate in Selangor.

In general, the experimental designs render statistical analysis* and interpretation difficult. In most cases, the layout is systematic: in some cases treatment effects are confounded with block effects. In all cases, the stocks consist of illegitimate seedling families, which implies not only that the material is variable, but also that the experiment contains a unique population which can never be repeated (BLACKMAN *et al.*, 1957).

The experiments may be divided into several categories:

1. Straightforward comparison of stocks and scions in various combinations: Field 1A, Fields 28 and 29, Field 43 and Bukit Rajah Estate.
2. Twinned seedling experiments: Fields 4C and 22B.
3. Height of budding experiment, i.e., variations in the proportion of stock to scion are considered: Field 10.

The twinned seedling experiment in Field 22B contains several clonal scions and seedling stocks and hence can also be considered as a straightforward stock-scion comparison. The experiment in Field 43 has an additional treatment in that two different heights of opening for tapping were employed.

In general, results and records obtained before and during the Japanese occupation of Malaya are available only as brief summaries, or not at all. Tapping during the occupation was irregular, and declined in frequency and standard as the war progressed. In most cases fairly complete records are available from 1946 or 1947 onwards. Except where otherwise noted, tapping has been alternate daily on a half-spiral cut (S/2.d/2.100%), and yield has been recorded by weighing the coagulated contents of the cups twice a month. In most cases girth has been measured yearly, generally at 50 in. above the stock-scion union (or ground level). The results of these and of other, more specialised records will be dealt with under the individual experiments.

Where the term 'vigour' is used in this paper it refers to rate of growth; in all cases but one, this has only been measured as rate of increase in girth size. The exception occurs in Field 1A where seedling height has been used as an indication of vigour.

* Analyses of variance relating to these experiments are given in *Research Archives of the Rubber Research Institute of Malaya Document No. 15.* Analyses of Variance and Additional Information relating to 'Investigations into the Relationship between Stock and Scion in Budded Trees of *Hevea brasiliensis*' by B. R. Buttery, *J. Rubb. Res. Inst.* **17** (1961), Comm. 342.

COMMUNICATION 342

FIELD 1A

METHODS AND MATERIALS

This experiment was intended to investigate the value of three illegitimate seedling families (AVROS 49, AVROS 157 and PB 25) as stocks for four clones (BD 5, AVROS 157, PB 25 and AVROS 49). The stocks and scions were used in a systematic layout, in twenty-four blocks, each containing all combinations (twelve trees), plus six incomplete blocks near the road. The area was planted with seedling stumps in May 1934 and these were budded with the four clonal scions in December 1935.

The tapping history of the experiment was as follows:

First panel opened in 1942 (?) at 40 in.

Second panel opened in April 1949 at 40 in.

Third panel (first renewal) opened in April 1953 at 44 in.

RESULTS

Growth

The only available data on the growth of the seedlings before budding are height measurements taken in May 1935. An analysis of variance showed that the AVROS 49 and PB 25 seedling families, with mean heights of 226.5 cm and 228.2 cm respectively, did not differ significantly from each other, but that AVROS 157 seedlings had a significantly lower mean height (170.5 cm) than the other two.

Girth measurements of buddings were taken in 1940 and 1947; *Table 1* shows the stock-scion means for both years. The number of trees per stock-scion combination ranges from 20 to 29. It was shown by an analysis of variance that in both years there was a highly significant scion effect on girth, but only in 1947 was a stock effect established with confidence. In neither year was there a significant interaction between stocks and scions.

TABLE 1. FIELD 1A. MEAN GIRTHS OF BUDDINGS IN 1940 AND 1947, IN CM

Measurements taken at 40 in. from the union in 1940 and at 50 in. in 1947

Stock	Scion				Stock means
	AVROS 157	PB 25	AVROS 49	BD 5	
1940					
AVROS 157	36.2	40.8	41.2	31.1	37.3
AVROS 49	35.4	37.8	38.9	29.5	35.4
PB 25	37.1	40.6	37.4	29.4	36.1
Scion means	32.6	39.8	39.2	30.0	
1947					
AVROS 157	67.1	67.5	66.4	48.5	62.4
AVROS 49	61.5	63.0	61.0	45.9	57.8
PB 25	63.1	59.9	55.5	42.4	55.2
Scion means	63.9	63.5	61.0	45.6	

In 1940, the scions PB 25 and AVROS 49 were similar in mean girths, and both exceeded significantly the mean girth of scion AVROS 157, which in turn was significantly greater than that of BD 5. In 1947, there was no significant difference between AVROS 157, PB 25 and AVROS 49, but the mean girth of BD 5 was still significantly less than that of the other three. AVROS 157 seedling stocks were associated with the highest mean girth in 1947.

Yield

Table 2 shows the annual mean yield per tree per tapping for each stock-scion combination. The overall mean yields for each

TABLE 2. FIELD 1A. MEAN ANNUAL YIELDS FOR THE PERIOD 1947-52 IN GRAMS PER TREE PER TAPPING

Stock	Scion	1947	1948	1949	1950	1951	1952	Mean 1947-52
AVROS 49	BD 5	29.8	29.0	24.6	22.5	25.9	22.4	25.7
	AVROS 157	34.6	46.1	28.9	25.3	34.6	35.8	34.2
	AVROS 49	40.7	43.3	31.1	30.8	30.2	27.9	34.0
	PB 25	53.9	51.6	49.0	47.2	48.1	53.9	50.6
AVROS 157	BD 5	27.7	24.8	26.4	25.5	31.9	27.2	27.2
	AVROS 157	32.4	42.9	31.6	30.3	39.4	40.1	36.1
	AVROS 49	44.9	49.3	38.8	37.9	36.6	33.2	40.1
	PB 25	46.0	43.8	43.7	46.4	52.4	51.6	47.3
PB 25	BD 5	26.2	27.2	24.0	20.0	23.3	19.5	23.4
	AVROS 49	34.0	35.6	23.8	24.5	24.6	22.2	27.4
	AVROS 157	30.1	42.2	28.7	26.9	34.7	34.3	32.8
	PB 25	47.1	49.0	41.1	45.1	47.4	46.6	46.0

TABLE 3. FIELD 1A. STOCK AND SCION MEAN YIELDS FOR THE PERIOD 1947 TO 1952, IN GRAMS PER TREE PER TAPPING

Calculated from individual tree totals for the period

Stock	Scion				Stock means
	PB 25	AVROS 49	AVROS 157	BD 5	
AVROS 157	46.2	40.1	35.0	26.0	36.8
AVROS 49	47.9	33.8	31.1	24.3	34.3
PB 25	43.3	27.5	32.1	21.6	31.1
Scion means	45.8	33.8	32.7	24.0	34.1

seedling stock for the period 1947—52 were analysed (like the mean girth values) on an individual tree basis as if the treatment combinations were completely randomised within the experimental area. Of the scions, PB 25 was significantly higher yielding than any of the other clones; AVROS 49 and AVROS 157 were similar in yield, but both were better yielding than BD 5. PB 25 and BD 5 were consistently the highest and lowest yielding scions, irrespective of stock.

Stock means did not differ significantly when the yields of the four scions were averaged.

With three of the scions there is no evidence for stock influence, but with AVROS 49 scion, PB 25 stock is associated with a significantly lower yield than AVROS 157 stock (*Table 3*). This inferiority of PB 25 stock when used with AVROS 49 scion has not affected the PB 25 stock mean sufficiently to induce a significant difference in the stock means, or to establish the presence of stock-scion interaction.

DISCUSSION

It is seen that the least vigorous seedling family (judged by height measurements before budding), AVROS 157, is associated with the most vigorous growth of buddings. This effect is, however, only noticeable after several years of tapping (in 1947) and is not apparent in the 1940 girth measurements.

There were significant differences in the height of the seedling stocks before budding but it is not known to what extent the height of seedlings may be used as a measure of total growth. No records are available concerning degree of branching of the families, and this is a factor which could complicate interpretation of results. It has recently been shown graphically (though details are not given here) that in this experiment there was no clear-cut relationship between seedling height before budding and the vigour of the scion subsequently budded on it (Rubber Research Institute of Malaya, 1960).

The stock (AVROS 157 seedling family) which gave the most vigorous growth of buddings in 1947, appears to be associated with the highest mean yield. As a clone, AVROS 157 is the best scion material for girth (in 1947, at least), but not for yield.

FIELDS 28 AND 29

METHODS AND MATERIALS

In this experiment four illegitimate families of seedling stocks (Tjir 1, Pil B84, PB 23 and AVROS 256) were used with five clonal scions (Tjir 1, Pil B84, PB 23, Gl 1 and Pil D65). Fields 28 and 29 were separated by the fifty-acre Field 27. Each field was divided in two equal blocks, and each block into four plots representing the four illegitimate seedling families. In November 1936, the trees in each plot were budded with the five scions in succession, one or two unbudded trees being left before the next group of five scions. The tapping history of the experiment is given below:

First panel opened in 1940 (?) at 40 in.
Second panel opened in Jan. 1950 at 40 in.
Third panel (first renewal) opened in Oct. 1953 at 40 in.
Fourth panel (first renewal) opened in July 1957 at 40 in.

It appears that little or no tapping was carried out during the Japanese Occupation; the tapping cut was at a height of 21 in. in November 1947.

RESULTS

Growth

The girth measurements of the unbudded seedlings (*Table 4*) were considered separately and no significant differences between the various families were found.

Girth records for 1939, 1949 and 1955 (*Table 5*), as well as the girth increment between 1939 and 1949, have been analysed. The 1939 figures give an indication of growth during immaturity, whilst the 1949 and 1955 records show the influence of several years of tapping. During the interval 1939–1949, the trees were tapped for about four years.

TABLE 4. FIELDS 28 AND 29. MEAN GIRTHS OF SEEDLING FAMILIES IN CM

Family	1939	1949	1955	Increment 1939—1949
AVROS 256	38.1	90.1	100.1	52.0
PB 23	37.9	88.0	98.0	50.1
Tjir 1	41.2	89.9	97.6	48.6
Pil B84	36.2	84.4	94.7	48.2

TABLE 5. FIELDS 28 AND 29. MEAN GIRTHS IN CM OF ALL COMBINATIONS OF STOCK AND SCION IN 1939, 1949 AND 1955, WITH GIRTH INCREMENTS FOR THE PERIOD 1939—1949

Date and measurement	Stock	Scion					Stock means
		Tjir 1	Gl 1	Pil B84	PB 23	Pil D65	
Mean girth Dec. 1939	Pil B84	27.6	24.6	25.4	24.7	23.2	25.13
	PB 23	27.4	25.0	25.4	24.2	23.4	25.09
	Tjir 1	27.3	26.4	24.2	25.4	21.6	24.99
	AVROS 256	25.7	23.7	24.1	24.3	20.8	23.71
	Scion means	27.02	24.96	24.76	24.68	22.25	
Mean girth Jan. 1949	Pil B84	88.2	65.5	70.4	64.7	62.5	70.26
	AVROS 256	87.1	63.9	63.9	64.9	61.3	68.22
	PB 23	90.3	66.1	62.4	59.0	59.5	67.46
	Tjir 1	83.1	62.8	55.5	57.5	49.8	61.74
	Scion means	87.21	64.57	63.07	61.54	58.30	
Girth increment, 1939—49	Pil B84	60.6	40.8	45.0	39.9	39.3	45.13
	AVROS 256	61.4	40.1	39.9	40.6	40.5	44.51
	PB 23	62.9	41.1	37.0	34.8	36.1	42.41
	Tjir 1	55.8	36.3	31.3	32.1	28.2	36.76
	Scion means	60.19	39.61	38.31	36.85	36.06	
Mean girth April 1955	Pil B84	98.2	69.8	79.3	69.9	70.7	77.6
	PB 23	103.6	72.2	70.0	66.5	69.3	76.3
	AVROS 256	97.9	69.8	69.7	70.1	69.0	75.3
	Tjir 1	93.1	67.5	63.4	61.1	57.5	68.6
	Scion means	98.2	69.8	70.6	66.9	66.6	

TABLE 6. FIELDS 28 AND 29. ANNUAL MEAN YIELDS OF STOCKS IN GRAMS PER TREE PER TAPPING

Stock	1948	1949	1950	1951	1952	1953	1954	1948—54
Pil B84	43.5	41.0	39.0	36.3	38.6	35.4	24.0	36.9
PB 23	41.7	38.3	37.5	35.6	37.3	33.3	23.6	35.4
AVROS 256	39.9	35.7	36.4	34.0	38.1	33.1	20.4	34.0
Tjir 1	35.5	35.0	31.1	29.8	32.2	27.8	16.8	29.9

TABLE 7. FIELDS 28 AND 29. ANNUAL MEAN YIELDS OF SCIONS IN GRAMS PER TREE PER TAPPING

Scion	1948	1949	1950	1951	1952	1953	1954	1948—54
Tjir 1	72.6	69.6	73.0	65.2	73.8	71.8	52.6	68.4
Gl 1	46.5	36.1	44.9	38.1	33.1	23.3	15.2	34.0
Pil B84	31.2	30.0	25.8	23.8	27.8	24.3	16.1	25.6
Pil D65	24.6	24.6	18.5	23.4	24.7	20.8	11.2	21.2
PB 23	25.9	27.0	17.9	19.0	23.3	21.8	10.9	20.9

TABLE 8. FIELDS 28 AND 29. STOCK-SCION MEAN YIELDS FOR THE PERIOD 1948—1954 IN GRAMS PER TREE PER TAPPING

Stock	Tjir 1	Gl 1	Pil B84	Pil D65	PB 23	Stock means
Pil B84	72.0	34.9	34.3	21.3	21.9	36.9
PB 23	75.1	35.8	24.2	22.4	19.5	35.4
AVROS 256	67.5	34.7	24.1	21.2	22.4	34.0
Tjir 1	59.1	30.7	20.0	19.9	19.7	29.9
Scion means	68.4	34.0	25.6	21.2	20.9	34.0

In an analysis of variance of the figures given in *Table 5* a very highly significant scion effect was found in all the periods considered, but a stock effect was apparent only in the later records.

In 1939, the scion Tjir 1 was associated with the highest mean girth, which exceeded significantly that of the other clones. The scions Pil B84, PB 23 and Gl 1 were similar to each other, but each showed significantly better growth than Pil D65.

In the 1949 and 1955 measurements, the mean girth for the stock Tjir 1 was markedly less than that of any other stock. As a scion, however, Tjir 1 had the greatest mean girth, significantly better than that of any other clone. As in 1939, the scion Pil D65 had the lowest mean girth, but in 1955 it did not differ significantly from Gl 1, Pil B84 and PB 23, while in 1949 it was significantly inferior to Tjir 1 and Gl 1 only.

The difference between Pil B84, PB 23 and AVROS 256 stocks in respect of girth increment in the period 1939—49 was negligible, but the mean girth increment for Tjir 1 stock was significantly less than the mean of any other stock. The girth increment of Tjir 1 scion was significantly higher than that of any of the other clones, which, however, did not differ significantly amongst themselves.

In no case was the interaction between stock and scion established with confidence.

Yield

Table 6 gives yearly values for mean yield for each stock, while *Table 7* gives mean values for scions. *Table 8* gives the stock-scion interaction means averaged over the period 1948–1954.

An analysis of variance has been carried out for each year, and also for the overall yield for 1948–1954 (*Table 9*). In each analysis the mean square for scions is extremely high relative to its error (b) and to the other mean squares. The relative magnitudes of the scion error (a) and the stock error (b) are unusual in that (a) is less than (b) in 7 of the 8 analyses. This probably arises because of a defect in the design of the experiment whereby the gross scion differences are compared in sub-plots and the stock effects assigned to main plots; the converse arrangement would have been more efficient. It is possible that the trial has underestimated the magnitude of error (a). Consequently, in *Table 9*, stock effects are not only tested against error (a), but also confirmed by testing against the pool of errors (a) and (b). The following discussion of stock differences refer to tests using error (a). The use of the pooled error does not grossly alter the main findings.

Stock effects are established for mean yields of 1948, 1950, 1953 and 1954, and also for the overall mean yields for 1948–1954. In all years the stock Tjir 1 is associated with the lowest yield (*Table 6*), and Pil B84 stock with the highest yield. The stocks PB 23 and AVROS 256 are similar in yield (and these in turn cannot be distinguished statistically from Pil B84); the yield for PB 23 is numerically greater than that of AVROS 256 in all years except 1952.

The scion differences are very highly significant in all years (*Table 9*). The trees budded with Tjir 1 scion have the highest yield, and this exceeds significantly that of Gl 1. Both Tjir 1 and Gl 1 scions are associated with markedly higher yields (for the period 1948 – 54) than any of the other clones. The scions PB 23 and Pil D65 yield poorly and do not differ appreciably from each other. The scion Pil B84 is significantly higher yielding than PB 23 and Pil D65 in three years only, 1948, 1949 and 1950. In 1953 and 1954, Gl 1, Pil B84, Pil D65 and PB 23 have similar yields. It should be noted that from 1953 tapping was carried out on bark on first renewal.

The interaction between stock and scion is not established with confidence in any analysis. It is noteworthy, however, that Pil B84 budded on Pil B84 stocks yields more than it does when budded on any other stock (*Table 8*). Furthermore, scion Tjir 1 budded on Tjir 1 stocks has a lower yield than when budded on the other stocks. Thus, these two combinations, Pil B84 on Pil B84 stocks and

TABLE 9. FIELDS 28 AND 29. ANALYSES OF VARIANCE OF YIELD OF BUDDED TREES IN GRAMS PER TREE PER TAPPING

Source	d.f.	Mean squares							
		1948	1949	1950	1951	1952	1953	1954	1948-54
Stocks	3	231.734	148.194	232.094**	171.381	168.985	224.356	222.728**	181.405*
Blocks	3	94.298	10.123	529.580***	729.910***	382.965*	291.644*	237.734***	230.184*
Error(a)	9	70.813	112.852	30.753	45.542	78.626	66.833	18.777	43.198
Scions	4	6488.506***	5460.562***	8733.886***	5723.408***	7165.191***	7787.798***	5010.958***	6369.014***
Stocks × scions	12	67.913	55.123	51.543	42.936	66.084	38.528	124.883	48.743
Error(b)	48	74.588	81.015	100.850	118.117	108.250	79.495	70.690	74.706
Stocks against pool of errors (a) and (b)		*	NS	NS	NS	NS	*	*	NS

TABLE 10. FIELDS 28 AND 29. ANNUAL MEAN YIELDS OF UNBUDDED SEEDLING FAMILIES IN GRAMS PER TREE PER TAPPING

Seedling family	1948	1949	1950	1951	1952	1953	1954	1948—54
Pil B84	48.3	35.4	39.0	37.6	42.8	35.0	32.4	38.6
PB 23	57.0	47.5	54.3	48.0	47.5	49.3	41.3	49.3
Tjir 1	59.2	46.4	56.0	51.9	53.6	46.9	45.4	49.9
AVROS 256	58.3	49.0	49.9	48.6	56.6	50.4	40.7	50.5

Tjir 1 on Tjir 1 stocks, are to some extent exceptional.

Seedling yields (*Table 10*), obtained from the unbudded trees in each plot, were analysed separately for each year and also for the mean values over the whole period. Differences between the seedling families were not established with confidence. It will be noticed, however, that in every year Pil B84 seedlings yield appreciably less than any of the other families and it is likely that this is a real difference. There is certainly little or no difference between PB 23, Tjir 1 and AVROS 256 seedlings in regard to yield capacity.

DISCUSSION

Considering the scions, it will be seen that the most vigorous scion Tjir 1 is also the highest yielder. Tjir 1 not only produces most latex, but also continues to grow the fastest whilst under tapping.

With the stocks, it will again be seen that there is some correspondence between vigour of growth and yield; Tjir 1 stocks produce the least growth under tapping and also are associated with a lower yield. On the other hand, Pil B84 stocks produce the fastest growth during tapping and are associated with the highest yields. There is some indication that Pil B84 scion is best on Pil B84 stocks and that Tjir 1 scion grows least well on Tjir 1 stock.

Differences between unbudded seedling families have not been conclusively established, but it seems likely that Pil B84 yields less than the other three. Thus in this experiment the seedling family which appears to be the poorest yielding makes the best stock material. Similarly one of the best seedling families (and as a clone, undoubtedly the best scion material), Tjir 1, makes the worst stock material.

ESTATE EXPERIMENT

METHODS AND MATERIALS

In this experiment four illegitimate seedling families (Tjir 1, Pil B84, BD 10 and SR 9) and unselected seedlings were used as stocks for four clonal scions (Tjir 1, SR 9, BD 10 and Pil B84) and for 'self-buddings' in which the buds were grafted on to the stocks from which they had been taken. The experimental layout consisted of two randomised blocks, in which scions formed the main plots and stocks the sub-plots. Budding was done in April – May 1940. The tapping history was as follows:

	Buddings	*Seedlings*
First panel opened	April 1948 at 40 in.	April 1948 at 20 in.
Tapped on full spiral cut	Jan. 1949 to April 1950	Sept. 1949 to April 1950
Second panel opened	April 1953 at 36 in.	June 1951 at 30 in.
Third panel (first renewal) opened	June 1957 at 55 in.	Nov. 1954 at 50 in.

Yield was recorded by cup-coagulation of latex from the central twenty-five trees in each sub-plot.

RESULTS

Growth

Mean girths for all stock-scion combinations in 1948 and in 1959 are shown in *Table 11*. These values have been analysed

TABLE 11. ESTATE EXPERIMENT. MEAN GIRTHS IN INCHES, 1948 AND 1959
Measurements taken at 50 in. from union for buddings, and 50 in. from ground for seedlings

Stock	Scion				Stock means	'Scion'		Stock means, all categories of scion
	SR 9	BD 10	Tjir 1	Pil B84		Self buddings	Unbudded seedlings	
1948								
SR 9	16.3	23.1	24.1	24.3	21.97	24.2	23.0	22.53
Unselected	17.0	22.7	23.6	24.1	21.89	23.9	23.8	22.56
Pil B84	17.4	22.5	23.5	24.8	22.07	25.1	26.0	23.23
Tjir 1	17.6	22.5	25.2	23.6	22.25	23.7	26.7	23.24
BD 10	18.5	23.4	24.6	24.9	22.86	24.4	26.0	23.65
Scion means	17.38	22.85	24.23	24.38	22.21	24.30	25.12	23.04
1959								
SR 9	25.0	30.7	31.1	33.6	30.14	31.2	30.0	30.30
Unselected	24.4	30.9	29.6	30.9	28.97	31.7	32.1	29.95
Pil B84	26.5	29.4	29.3	32.5	29.44	31.9	33.0	30.45
Tjir 1	26.4	29.5	31.2	30.7	29.46	29.9	33.3	30.18
BD 10	26.6	30.2	31.3	32.3	30.12	32.0	33.3	30.97
Scion means	25.79	30.16	30.53	32.03	29.62	31.36	32.36	30.37

TABLE 12. ESTATE EXPERIMENT. ANALYSES OF VARIANCE OF 1948 AND 1959 GIRTH MEASUREMENTS

Source	d.f.	All categories of scion		Excluding seedlings and self-buddings		
		1948 Mean squares	1959 Mean squares	d.f.	1948 Mean squares	1959 Mean squares
Blocks	1	1.41	1.32	1	0.73	2.97
Scions	5	82.39***	57.48**	3	108.43**	71.99*
Blocks × scions	5	0.59	3.69	3	0.86	4.12
Stocks	4	2.82**	1.77	4	1.21***	1.99*
Stocks × scions	20	1.16	2.31	12	0.64**	1.93*
Error	24	0.51	1.18	16	0.13	0.49
Total	59			39		

in two ways (*Table 12*); (a) including every plot, (b) excluding those plots in which stocks were unbudded or budded with their own buds.

It will be seen that a scion effect is evident in both years, 1948 and 1959, though the level of significance appears to decrease with time. The analysis excluding seedlings and self-buddings show the scion effect to be less marked, though this is probably merely the results of having less degrees of freedom for the F - test. SR 9 is by far the least vigorous scion, and its mean girth is significantly less than that of any other clone in both years analysed. In 1948, the scion BD 10 is associated with a higher mean girth than SR 9 and a lower mean girth than the other scions; Pil B84, Tjir 1, self-buddings and seedlings all have similar mean girths. In 1959, BD 10 scion is significantly larger than SR 9, but does not differ appreciably from the other scions.

A stock effect is established in 1948 and in 1959 when seedlings and self-buddings are excluded from the analysis, but when all categories of scion are considered together the effect is established in 1948 only (*Table 12*). In 1948, BD 10 stock (*Table 11*) is associated with a significantly larger mean girth than the other four stocks when averaged over the four clonal scions, but, when all scion categories are considered, BD 10 stock is established as giving a larger girth than SR 9 and unselected stocks only; Tjir 1 and Pil B84 do not differ significantly from each other or from the other three stocks. In 1959, the mean girths of SR 9 and BD 10 stocks are established as significantly larger than that of unselected stocks when averaged over the four true scion categories.

An analysis of variance of the girth increments for the period 1948 – 59 has also been carried out, but no significant effects of stocks or of scions were detected.

Yield

The mean yields in grams per cup-lump per tapping for the period March 1948 to December 1959, are shown in *Table 13*. The method of statistical analysis has a considerable effect on the inferences to be drawn from the data; stocks, but not scions, showed a significant effect when all the categories of scions were considered, while scions, but not stocks, had a significant effect when seedlings and self-buddings were excluded. No stock-scion interaction was established with confidence.

Tjir 1 was the highest yielding scion, but differed significantly in yield only from SR 9 (when self-buddings and seedlings were excluded). Amongst the stocks the unselected seedlings were significantly lower yielding

TABLE 13. ESTATE EXPERIMENT. MEAN YIELDS FOR PERIOD 1948 TO 1959 IN GRAMS PER TREE PER TAPPING

Stock	Scion				Stock means	'Scion'		Stock means, all categories of scion
	SR 9	Pil B84	BD 10	Tjir 1		Unbudded seedlings	Self buddings	
Unselected	27.4	27.1	31.60	31.3	29.37	23.6	27.6	28.11
BD 10	25.7	28.7	29.5	33.3	29.31	30.0	30.0	29.55
SR 9	27.7	30.5	30.2	33.2	30.42	29.2	30.0	30.15
Pil B84	27.9	29.1	30.5	32.8	30.09	33.2	31.6	30.87
Tjir 1	26.2	28.0	31.3	36.2	30.42	33.4	31.6	31.12
Scion means	26.98	28.71	30.64	33.37	29.92	29.88	30.19	29.96

than Tjir 1 and Pil B84 when all scions were considered, but there was no significant difference when considering only the conventional clonal scions.

DISCUSSION

The yield analysis suggests that there is little to choose between the seedling families when used as stocks. The significant depression in the overall mean for unselected seedling stocks appears to be mainly the result of the low yields of the *unbudded* and *self-budded* unselected seedlings.

When considering the analysis of girth measurements, it should be noted that the error mean square is remarkably small, probably smaller than can be justified in view of the likely errors in measuring the trees. Although significant stock effects on girth appear to have been established, the effects are small and are probably of little consequence in practice. Scion effects are, however, clearly revealed and are of some importance.

Some relationship between girth and yield may be seen in the association between the lowest mean yield and the lowest mean girth in SR 9 scion. On the other hand, the largest trees (seedlings) do not produce the most latex, although they do not differ significantly in yield from the highest yielding scion, Tjir 1.

Amongst stocks, the unselected seedlings are associated (although not with consistent significance) with the smallest girth measurements and lowest yields. The unselected seedlings themselves yield more highly than would be expected; they may be low grade clonal seedlings, but the actual source is not recorded.

It should be noted that the sequence of stock yield means (with clonal buddings) does not differ greatly from that of the yields of the unbudded seedlings (*Table 13*). The most vigorous stocks (BD 10 and SR 9) are not especially high yielding.

A comparison of unbudded and self-budded seedling families should give an indication of the effect of the budding operation itself, as distinct from a scion effect. It is apparent in this experiment that no differences between unbudded and self-budded seedlings have been established with confidence; it may, however, be indicative of some small depressing effect of budding, that the girth figures of self-budded trees are slightly below those of the unbudded seedlings.

FIELD 43

METHODS AND MATERIALS

Nine illegitimate seedling families were used as stocks for three clonal scions. Within each of three main plots (representing the clonal scions Pil B84, Tjir 1 and PB 86), the illegitimate seedling families were laid out in double rows running east to west, randomised within each plot. Planting was with budded stumps in October – November 1941. Alternate trees within each row were opened for tapping at a height of 20 in., while the remainder were opened at 40 in. from the stock/scion union.

The illegitimate seedling families used as stocks were:

Lecointe (small) Entruncamento Brazil Import	Bahau Estate (Dunlop Estates). These were late imports from Brazil, obtained through the Botanical Gardens. Bogor, Java.
Hevea spruceana	Jungle plot B, and Carey Island. These were almost certainly hybrids between *H. spruceana and H. brasiliensis.*
PB 86 AVROS 163 Pil B84 Tjir 1 Unselected	R.R.I. Experiment Station.

The tapping history of the experiment is given below:

	High opening	*Low opening*
First panel	Aug. 1948 at 40 in.	Aug. 1948 at 20 in.
Second panel	Aug. 1952 at 40 in.	Aug. 1950 at 40 in.
Third panel (first renewal)	April 1956 at 40 in.	Aug. 1954 at 40 in.
Fourth panel (first renewal)	—	Aug. 1958 at 40 in.

TABLE 14. FIELD 43. MEAN GIRTHS IN INCHES, 1946, 1951 AND 1959

Stock	Scion											
	1946				1951				1959			
	Tjir 1	Pil B84	PB 86	Stock means	Tjir 1	Pil B84	PB 86	Stock means	Tjir 1	Pil B84	PB 86	Stock means
Entruncamento	15.6	12.7	12.2	13.5	27.5	26.5	23.1	25.7	37.1	35.4	28.3	33.6
H. spruceana	16.2	14.1	14.4	14.9	26.7	25.6	23.6	25.3	34.5	33.4	30.2	32.7
AVROS 163	15.2	12.6	13.6	13.8	26.1	24.4	24.7	25.1	32.2	34.4	31.1	32.6
Unselected	16.7	12.7	12.0	13.8	26.4	28.6	23.4	26.1	35.2	31.4	30.5	32.4
Tjir 1	15.7	13.9	13.6	14.4	27.8	29.5	23.3	26.9	35.4	31.4	29.0	31.9
Brazil Import	15.4	14.0	11.0	13.5	26.4	26.5	20.5	24.5	33.4	35.5	26.2	31.7
Lecointe	15.9	12.5	14.2	14.2	26.0	23.1	23.8	24.3	33.4	31.0	29.8	31.4
Pil B84	15.8	12.5	11.8	13.4	26.9	24.6	22.7	24.7	33.2	31.7	28.7	31.2
PB 86	13.9	12.7	11.2	12.6	25.4	25.1	21.5	24.0	32.7	30.8	29.7	31.1
Scion means	15.6	13.1	12.7		26.6	26.0	23.0		34.1	32.8	29.3	

RESULTS

Growth

The mean girth figures for all combinations of stock and scion in 1946, 1951 and 1959 are shown in *Table 14*. The number of trees differs slightly from year to year. Tjir 1 scions are consistently larger than PB 86 scions, though it must be noted that some of the difference may be due to 'block' differences. In 1946, the scions Pil B84 and Tjir 1 were similar in size, and both were significantly larger than PB 86.

Differences between stock means were not established with confidence in any year. No useful analysis of height effects on girthing could be carried out, since the trees did not receive the same 'treatment' all the time. For instance, the trees initially opened at 20 in. changed in 1950 to a 40 in. panel, and therefore became the 'high' series, and the same applied to other panel changes.

Yield

Mean yields (grams per tree per tapping) for the period 1948 to 1959 are shown in *Table 15*. In an analysis of variance, stock effects on yield were established with confidence. AVROS 163 and Pil B84 seedling stocks were associated with the highest yields, which exceeded significantly the mean yield of *H. spruceana* stocks. The remaining six seedling stocks did not differ significantly from each other, nor from AVROS 163, Pil B84 and *H. spruceana*.

Tjir 1 scions yielded appreciably more than both PB 86 and Pil B84, which were very similar to each other. Scion effects may, however, have been confused with block effects.

The effect of heights of tapping did not quite reach significance level when the mean square for heights was tested, in the most conservative way, against the heights × scions interaction mean square. There can be little

TABLE 15. FIELD 43. MEAN YIELDS OF BUDDINGS ON HIGH AND LOW TAPPING CUTS FOR THE PERIOD 1948-1959, IN GRAMS PER TREE PER TAPPING

Stock	Scion								
	Tjir 1		Pil B84		PB 86		Stock × height means		Stock means
	Low	High	Low	High	Low	High	Low	High	
AVROS 163	59.4	44.4	41.8	36.2	48.3	33.3	49.8	38.0	43.9
Pil B84	64.0	46.4	45.7	34.8	42.0	27.8	50.6	36.3	43.4
Entruncamento	53.1	45.4	38.6	36.6	38.3	30.5	43.3	37.5	40.4
Tjir 1	55.4	43.1	34.5	29.8	38.6	28.3	42.8	33.7	38.2
PB 86	53.2	40.6	31.0	29.3	37.4	28.7	40.5	32.9	36.7
Brazil Import	44.6	38.3	42.0	38.4	31.8	24.1	39.5	33.6	36.5
Lecointe	50.6	41.9	29.2	28.4	36.6	30.1	38.8	33.5	36.1
Unselected	50.9	40.3	29.5	27.5	36.9	28.8	39.1	32.2	35.6
H. spruceana	44.5	42.9	28.5	29.3	30.5	29.8	34.5	34.0	34.2
Scion × height means	52.9	42.6	35.6	32.3	37.8	29.0	42.1	34.6	
Scion means	47.7		33.9		33.4				

doubt, however, that the height effect was a real one, and if the test were made against the higher order interaction (heights × stocks × scions), height of tapping would be shown to have a very highly significant effect. The interactions between heights and scions and between heights and stocks were also well established.

In *Table 15* the yield of the low cut exceeds the yield of the high cut with all combinations of stock and scion, except one: with Pil B84 on *Hevea spruceana* stock, the yield of the high cut is slightly greater than that of the low cut. It will be further seen that, in general, the higher yielding stocks are associated with a larger 'height' effect, i.e., the stock × height interaction. There appears to be a similar effect with scions (largest height difference with highest yielding clone) but owing to inadequate replication there must be more doubt about this.

No reasonable test of stock-scion interaction can be made on this data.

DISCUSSION

It is apparent that the most vigorous scion (Tjir 1) also yields the most latex. On the other hand, no effect of stocks on girth size has been established, and indeed, one of the highest yielding stocks (Pil B84) produces one of the least vigorous buddings. It seems reasonable to assume then, that the stock effect on yield may be attributed, not to any effect on girth but either to the inherent yield capacity of the seedling tissues or to some indirect action on the yield capacity of the scion.

Over the period 1948 to 1959, one series of yield records has been taken from trees tapped on the average 20 in. higher on the trunk than the other series; the actual trees in each series alternate from 'high' to 'low' status, as tapping panels are changed. It has been established that the stock effect on yield is greater on the low cut than on the high cut. This indicates that the stock effect on the yield of the tree is fairly localised, near the stock itself, and there is no general increase in the yield capacity of the scion. The simplest explanation is that the higher yielding stocks have more latex vessels and thus provide a larger drainage area for tapping. With a very low yielding stock material, such as *H. spruceana* seedlings, the normal increase in yield found near the base of a scion is offset by the greatly reduced yield capacity of the stock itself; *H. spruceana* has remarkably few latex vessels and yields very poorly.

FIELD 4C

METHOD AND MATERIALS

This experiment was set up to investigate the relationship between scions and stocks using twinned seedlings. 'Twinning' consists of dividing freshly germinated seeds longitudinally with a razor in such a way that half the root, shoot and seed is allotted to each half. If the twinning operation is successful, two seedling trees of identical genetical constitution are produced.

Sixty-four pairs of twinned seedlings of Pil A44 were planted in the western part of the field, while fifty-six pairs of twinned seedlings of Pil B58 were planted in the eastern part. Eight untwinned seedlings of each illegitimate seedling family were planted as controls. In April 1932, four clones (PB 186, Tjir 1, BD 5 and Pil D65) were used for budding, each clone being confined to a pair of rows (representing pairs of twinned seedlings) running the length of the field. Only one member of each pair of twins was budded; a number of pairs of twins were left unbudded. Details of the tapping history of the experiment are as follows:

First panel opened in Jan. 1937 at 32 in.
Second panel opened in Jan. 1941 at 36 in.
(Rested from Jan. 1942 – May 1942, and June 1945 – March 1947).
Third panel (first renewal) opened in Sept. 1947 at 42 in.
Fourth panel (first renewal) opened:
(a) buddings in Jan. 1951 at 52 in.
(b) seedlings in Sept. 1951 at 42 in.
Fifth panel (second renewal) opened:
(a) buddings in Jan. 1955 at 52 in.
(b) seedlings in Oct. 1955 at 42 in.

TABLE 16. FIELD 4C. MEAN GIRTHS IN INCHES AND CORRELATION COEFFICIENTS OF (a) BUDDED AND (b) UNBUDDED MEMBERS OF PAIRS OF TWINNED SEEDLINGS

Girth measurements taken at 50 in. from union in 1940, 1948 and 1952; at 60 in. in 1956

One member (a) of pair budded with	1940				1948				1952				1956			
	No. of pairs	Girth a	Girth b	Corr. coef. r	No. of pairs	Girth a	Girth b	Corr. coef. r	No. of pairs	Girth a	Girth b	Corr. coef. r	No. of pairs	Girth a	Girth b	Corr. coef. r
PB 186	14	26.4	30.3	-0.11	15	37.2	38.2	-0.34	13	40.5	41.1	-0.31	13	42.5	40.6	-0.25
Tjir 1	18	27.8	27.1	-0.01	16	40.7	34.4	0.51*	10	40.7	32.9	0.14	10	42.0	33.5	0.13
BD 5	11	20.9	30.0	0.00	12	22.8	39.3	-0.11	8	25.2	39.3	0.06	8	25.2	39.4	0.00
Pil D65	9	27.0	29.6	-0.08	16	35.2	37.4	0.39	13	38.3	40.6	0.59*	13	38.9	40.6	0.47
Unbudded	36	28.8	27.7	0.53***	30	37.2	35.6	0.84***	21	41.2	40.0	0.84***	19	42.0	39.9	0.83***

TABLE 17. FIELD 4C. MEAN YIELDS IN GRAMS PER INCH OF TAPPING CUT AND CORRELATION COEFFICIENTS OF (a) BUDDED AND (b) UNBUDDED MEMBERS OF PAIRS OF TWINNED SEEDLINGS

One member (a) of pair budded with	1940				1948				1949				1950				1952			
	No. of pairs	Yield a	Yield b	Corr. coef. r	No. of pairs	Yield a	Yield b	Corr. coef. r	No. of pairs	Yield a	Yield b	Corr. coef. r	No. of pairs	Yield a	Yield b	Corr. coef. r	No. of pairs	Yield a	Yield b	Corr. coef. r
PB 186	14	1.6	1.6	0.56*	15	3.7	1.6	0.14	15	3.5	1.7	–0.21	15	3.2	1.7	–0.17	13	3.5	1.4	–0.15
Tjir 1	18	2.3	1.1	0.19	16	3.3	1.8	–0.03	16	3.6	1.8	0.18	16	3.4	1.9	0.36	11	2.6	1.3	–0.24
BD 5	11	0.9	1.5	0.62*	12	1.0	1.9	–0.02	12	0.9	1.9	–0.20	12	0.7	1.8	–0.10	8	0.6	1.5	–0.22
Pil D65	9	1.7	1.4	0.25	16	2.7	1.9	0.49	16	3.1	2.1	0.34	16	2.6	2.0	0.33	13	1.4	1.6	0.47
Not budded	36	1.8	1.6	0.67***	30	1.6	1.6	0.88***	30	1.7	1.7	0.91***	29	1.8	1.7	0.88***	21	1.3	1.3	0.79***
	1953				1954				1955				1956				1948 - 1956			
PB 186	13	2.9	1.4	0.09	13	2.4	1.4	0.22	13	2.4	1.8	–0.06	13	2.7	1.0	0.17	13	72.2	42.4	–0.26
Tjir 1	11	2.5	1.1	0.07	11	2.8	1.1	–0.15	11	1.6	1.6	0.01	11	2.2	1.2	–0.07	11	67.6	32.8	–0.11
BD 5	8	0.5	1.3	0.11	8	0.5	1.3	0.09	8	0.4	1.6	–0.13	8	0.5	0.8	–0.16	8	11.2	43.9	–0.08
Pil D65	13	1.6	1.4	0.70**	13	1.8	1.4	0.86***	13	0.7	1.7	0.09	13	1.1	1.1	0.22	13	40.9	44.6	0.61*
Not budded	21	1.2	1.2	0.78***	21	1.4	1.2	0.84***	21	1.8	1.7	0.85***	21	1.0	0.9	0.73***	20	43.1	42.8	0.90***

RESULTS

Growth

No significant (or even appreciable) differences between the two seedling families can be detected in this experiment, and there are, in any case, only a small number of twins available for analysis, so they are grouped together in the calculations. The correlation coefficients for girths of budded and unbudded members of pairs shown in *Table 16* reach significance level only in two cases: Tjir 1 buddings in 1948, and Pil D65 buddings in 1952. On the other hand, the unbudded twinned seedlings have very highly significant correlations for girths on all occasions.

Yield

It will be seen in *Table 17* that the correlation for yield per inch of tapping cut of budded and unbudded members of twinned seedlings seldom reaches significance level. PB 186 and BD 5 in 1940, and Pil D65 in 1953 and 1954 are the exceptions. Correlation coefficients based on the overall mean yields for the period 1948 to 1956 reach significance level only for Pil D65 buddings; the correlation for yield between pairs of unbudded twins is highly significant on all occasions.

Comparison of budded with unbudded twins

Figures are presented in *Table 18* for the average differences between budded and unbudded members of twinned seedlings in respect to yield per inch of tapping cut. Standard errors are shown for each difference, of which the significance is indicated in the usual way, with asterisks. PB 186 and Tjir 1 yield significantly more (per unit tapping cut) than their corresponding unbudded twins in all years except 1955. In this year, low values for buddings were probably caused by opening a new tapping panel 10 in. above second renewal bark, and thus tapping through a 'virgin bark island'. The seedling panel was not changed over until October 1955, and the height of opening was the same as the preceding (third) panel.

In general BD 5 seems to yield rather less than the corresponding seedling twins though this is not always established with confidence;

TABLE 18. FIELD 4C. MEAN DIFFERENCES IN YIELD (GRAMS PER INCH OF TAPPING CUT) BETWEEN BUDDED AND UNBUDDED MEMBERS OF PAIRS OF TWINNED SEEDLINGS

Year	PB 186		Tjir 1		BD 5		Pil D65	
	Budded minus unbudded yield	s.e.	Budded minus unbudded yield	s.e.	Budded minus unbudded yield	s.e.	Budded minus unbudded yield	s.e.
1950	1.47***	0.36	1.54***	0.32	-1.06**	0.32	+0.55*	0.24
1952	2.19***	0.25	1.34**	0.39	-0.91	0.44	− 0.17	0.23
1953	1.47***	0.33	1.43***	0.37	-0.80*	0.33	+0.21	0.27
1954	1.05**	0.33	1.67***	0.36	-0.84	0.41	+0.48*	0.23
1955	0.55	0.33	0.01	0.42	-1.22**	0.41	− 0.98***	0.23
1956	1.68***	0.23	1.02**	0.30	-0.34	0.22	− 0.03	0.19

Pil D65 yields slightly, but significantly, more in two years, 1950 and 1954.

DISCUSSION

The significant differences for yield per inch of tapping cut between budded and unbudded members of twins indicate that the scion has a very considerable effect on the yield capacity of a tree. In other words, a scion effect is well established. On the other hand, although there is a very high correlation between pairs and unbudded twins, there is, in general, a poor and insignificant correlation between the budded member and its corresponding unbudded twin. The implications of the results for twinned seedlings are also of importance to the next experiment reported (Field 22B) and will therefore be discussed more fully later in the paper.

FIELD 22B

METHODS AND MATERIALS

This was another 'twinned' seedling experiment, though on a larger scale than that in Field 4C. Five illegitimate seedling families (MAP (mixed), Pil A44, SR 9, PB 24 and PB 20) were used as twinned stocks in unreplicated main blocks, each seedling family occupying one block. In September 1934, alternate rows were budded with AVROS 50, Pil B84 and PB 186 in succession, but leaving a pair or rows of unbudded twins in each block. In the blocks formed with Pil A44 and PB 24 seedlings, AVROS 50 buddings were omitted. The trees were tapped as follows:

First panel opened in Jan. 1940 at 40 in.
Second paned opened in (?) 1944 at 40 in.
Third panel (first renewal) opened in Jan. 1949 at 40 in.

Fourth panel opened in Nov. 1952 at 44 in.

During the Japanese Occupation, the trees were rested from January to April 1942. Tapping was started again in May 1942, and continued until August 1945. Towards the end of this period tapping on the western side of the field (about half the experimental area) was irregular, and on re-occupation it was noticed that the height of tapping on this western half was about six inches above that on the eastern half of the field.

RESULTS

Growth

The correlation coefficients for girths of budded and unbudded members of pairs of twinned seedlings are shown in *Table 19*. It will be seen that significant correlations have been established for only a few combinations of stocks and scions; PB 186 on MAP, and Pil B84 on PB 20 for the individual years 1947 and 1954, and also for the increment during this period; Pil B84 on Pil A44 and AVROS 50 on SR 9 for both years but not the increment; PB 186 on Pil A44 and Pil B84 on SR 9, significantly correlated for the increment only; and AVROS 50 on PB 20 for 1954 only. On the other hand, significant correlations are established between unbudded pairs of twinned seedlings of all five families. In no case has a negative correlation been established with confidence.

Yield

Correlation coefficients for the mean yield for the period 1947 to 1954, and for the mean yield per inch of tapping cut for individual years are given in *Table 20*. The overall mean yield (1947–54) is based only on trees which were in tapping for the whole period, while the yearly records include all 'twins' tapped throughout the year. Measurements of length of tapping cut were not taken in 1951; hence results for this year are not presented.

It will be seen that in all cases the yields of pairs of unbudded twinned seedlings are significantly correlated; in most cases the correlation is very highly significant.

The majority of correlations for yield (or yield per inch of tapping cut) of twins in which one member is budded, do not reach significance level. PB 186 on MAP and on Pil A44; Pil B84 on MAP and on Pil A44 and on PB 20; AVROS 50 on MAP, and on SR 9

TABLE 19. FIELD 22B. MEAN GIRTHS IN INCHES AND CORRELATION COEFFICIENTS FOR (a) BUDDED AND (b) UNBUDDED MEMBERS OF PAIRS OF TWINNED SEEDLINGS

The 1947 and 1954 figures include all available figures for trees in tapping; figures for the 1947–54 girth increment include only trees in tapping for whole period

One member (a) of pair budded with	Illeg. seedling stock	1947				1954				Increment 1947—54			
		No. of pairs	Girth a	Girth b	Corr. coef. r	No. of pairs	Girth a	Girth b	Corr. coef. r	No. of pairs	Girth a	Girth b	Corr. coef. r
PB 186	MAP	20	27.1	33.0	0.52*	27	28.2	36.5	0.59**	16	2.8	3.5	0.55*
	Pil A44	19	28.2	33.4	0.39	22	30.0	36.9	0.37	14	3.4	3.9	0.72**
	SR 9	16	27.0	34.1	-0.14	20	29.3	36.2	0.23	11	3.2	4.3	0.51
	PB 24	19	25.9	33.7	-0.24	19	27.9	38.2	-0.34	13	2.4	5.0	0.54
	PB 20	17	26.7	30.9	0.05	19	29.3	36.0	0.10	15	3.1	4.2	0.29
Pil B84	MAP	14	31.1	31.9	0.37	15	37.7	39.7	0.26	8	7.9	6.8	0.12
	Pil A44	18	31.8	34.3	0.61**	19	36.8	39.6	0.49*	16	6.1	5.3	0.47
	SR 9	22	30.9	31.2	0.08	23	36.8	34.9	0.20	16	5.3	4.1	0.50*
	PB 24	22	30.0	34.6	-0.24	19	34.7	39.5	-0.32	16	5.1	4.0	-0.08
	PB 20	19	30.8	32.3	0.61**	20	37.4	34.6	0.72***	16	7.0	3.5	0.60*
AVROS 50	MAP	17	31.3	34.1	-0.07	17	35.9	38.0	0.13	10	5.8	4.4	-0.17
	SR 9	21	29.0	32.1	0.59**	20	32.8	35.4	0.51*	17	5.0	4.1	0.37
	PB 20	10	29.8	35.0	0.41	13	33.8	36.4	0.70**	10	5.5	4.3	0.39
Unbudded	MAP	23	32.1	31.4	0.75***	23	37.8	36.4	0.86***	17	4.8	3.9	0.65**
	Pil A44	20	30.9	32.5	0.70***	25	34.1	35.6	0.67***	15	4.4	4.1	0.61*
	SR 9	24	33.2	31.6	0.79***	23	37.7	35.6	0.78***	20	4.4	4.1	0.75***
	PB 24	15	30.9	32.8	0.72**	17	34.7	36.9	0.83***	8	4.2	4.9	0.92**
	PB 20	20	32.9	29.9	0.65**	23	35.8	33.9	0.60**	19	5.1	4.6	0.80***

TABLE 20. FIELD 22B. ANNUAL MEAN YIELDS IN GRAMS PER INCH OF TAPPING CU
AND CORRELATION COEFFICIENTS BETWEEN (a) BUDDED AND (

Figures for the overall mean yield (1947–1954) are based on

One member (a) budded with	Illeg. seedling stock	1947				1948				1949					
		No. of pairs	Yield a	Yield b	Corr. coef. r	No. of pairs	Yield a	Yield b	Corr. coef. r	No. of pairs	Yield a	Yield b	Corr. coef. r	No. of pairs	Yi a
PB 186	MAP	20	2.6	2.0	0.58**	21	2.1	1.6	0.56**	22	2.0	1.0	0.52	20	2.2
	Pil A44	19	2.9	1.8	0.42	18	1.9	1.6	0.38	18	2.3	1.0	0.10	16	2.3
	SR 9	17	2.5	2.7	0.17	16	2.0	2.8	–0.06	16	1.4	1.9	–0.36	14	1.6
	PB 24	19	2.1	2.9	0.37	16	1.6	2.6	0.08	19	1.3	1.8	0.09	17	1.5
	PB 20	18	2.5	2.4	0.38	18	2.5	2.5	0.47	18	1.8	1.6	0.04	17	2.4
Pil B84	MAP	14	2.9	1.7	0.60*	13	2.2	1.6	0.61*	14	1.6	0.8	0.30	13	2.3
	Pil A44	18	3.3	1.9	0.19	18	2.2	1.8	–0.02	17	1.9	1.1	0.43	17	2.3
	SR 9	22	3.0	2.4	0.08	20	2.8	2.1	0.24	20	1.8	1.3	0.41	18	2.2
	PB 24	22	2.8	2.9	0.14	17	2.4	2.2	0.24	22	1.7	2.0	0.15	19	2.2
	PB 20	19	3.0	2.1	0.52*	18	2.7	2.1	0.47	21	1.9	1.0	0.25	21	2.3
AVROS 50	MAP	17	2.4	2.4	0.46	14	1.9	1.5	0.17	15	1.4	1.7	0.40	15	2.1
	SR 9	21	2.3	2.2	0.60**	21	2.1	2.1	0.69***	17	1.0	1.3	0.55*	17	1.4
	PB 20	10	2.4	2.6	0.80**	10	2.4	2.6	0.71*	10	1.2	1.6	0.51	10	1.8
Unbudded twinned seedlings	MAP	23	2.4	2.4	0.87***	22	2.2	2.1	0.85***	25	1.4	1.3	0.72***	21	1.5
	Pil A44	20	1.8	1.8	0.70***	19	1.6	1.6	0.46*	23	1.0	1.0	0.80***	23	1.1
	SR 9	24	2.2	2.1	0.90***	22	2.2	2.0	0.90***	23	1.5	1.4	0.90***	23	1.7
	PB 24	15	2.6	2.5	0.92***	14	2.6	2.5	0.96***	15	2.0	2.0	0.92***	14	2.3
	PB 20	20	2.5	2.4	0.94***	20	2.5	2.3	0.93***	20	1.5	1.2	0.87***	20	2.0

, MEAN YIELDS IN GRAMS PER TREE PER TAPPING FOR THE PERIOD 1947-1954,
) UNBUDDED MEMBERS OF PAIRS OF TWINNED SEEDLINGS

y on trees which were in tapping for the whole period

1950		1952				1953				1954				1947-1954			
ld b	Corr. coef. r	No. of pairs	Yield a	b	Corr. coef. r	No. of pairs	Yield a	b	Corr. coef. r	No. of pairs	Yield a	b	Corr. coef. r	No. of pairs	Mean yield a	b	Corr. coef. r
1.4	0.44*	20	1.5	1.6	0.60**	27	1.2	0.8	0.18	27	1.2	0.9	0.10	16	29.3	28.9	0.68**
1.2	0.46	18	2.2	1.7	0.50*	23	1.4	0.7	0.12	22	1.3	0.9	0.23	14	41.4	29.0	0.55*
2.3	–0.64*	18	1.9	2.5	0.19	22	1·2	1.2	–0.14	19	1.4	1.4	0.05	11	33.0	47.2	–0.52
2.6	–0.24	18	1.9	2.6	–0.19	19	0.9	1.2	0.14	19	1.0	1.6	0.08	13	21.9	44.3	–0.11
1.9	0.15	18	2.3	2.2	0.26	19	1.3	1.2	–0.14	19	1.5	1.3	0.09	15	34.5	39.9	0.19
1.1	0.32	16	2.4	1.4	0.60*	18	1.5	0.7	0.05	15	1.8	0.9	0.15	8	54.9	30.1	0.10
1.3	0.53*	18	2.3	1.8	0.20	19	1.8	0.8	0.12	19	1.7	0.9	0.35	16	46.1	31.3	0.32
1.5	0.09	19	2.3	2.0	0.21	23	1.3	1.1	–0.09	19	1.6	1.3	0.13	16	42.8	39.4	0.05
1.9	0.19	20	2.7	2.8	–0.06	19	1.2	1.1	0.11	19	1.7	1.4	0.05	16	45.1	42.0	0.09
1.3	0.54*	20	2.8	1.9	0.15	21	1.6	0.7	0.64**	20	1.9	0.9	0.63**	16	49.3	32.6	0.58*
1.9	0.46	18	2.7	2.5	0.59*	21	0.9	1.1	–0.11	17	1.0	1.2	–0.08	10	36.3	47.9	–0.23
1.5	0.54*	19	2.2	2.0	0.66	21	0.8	0.8	–0.13	20	0.9	0.9	0.30	17	30.4	33.3	0.59*
2.0	0.61	14	2.1	2.0	0.60*	13	0.7	0.9	+0.47	13	1.3	1.1	0.58*	10	32.2	46.4	0.60
1.5	0.85***	21	2.2	2.2	0.76***	23	0.9	1.0	0.71***	23	1.2	1.2	0.71***	17	35.2	35.6	0.76***
1.3	0.55**	22	1.8	2.0	0.76***	27	0.7	0.7	0.56**	25	0.8	0.9	0.66***	15	28.2	28.9	0.82***
1.7	0.87***	22	2.3	2.0	0.82***	23	1.1	0.8	0.85***	23	1.3	1.2	0.84***	20	41.8	34.5	0.88***
2.8	0.76**	13	2.2	2.1	0.83***	17	1.3	1.3	0.85***	17	1.5	1.8	0.87***	8	38.9	44.7	0.91**
1.5	0.86***	21	2.2	1.9	0.78***	24	1.2	1.2	0.74***	23	1.3	1.3	0.73***	19	46.6	37.1	0.94***

and on PB 20, exhibit significant correlations in several years. There is, perhaps, a slight tendency for the highest number of correlations to appear when the tapping cut is near the end of the panel (i.e. near or on the stock) in 1948 and 1952, but this is by no means well established.

In 1950, a significant negative correlation is found for yield per inch of tapping cut of the PB 186 buddings on SR 9 twinned seedlings (*Table 20*). The correlation coefficient for the overall mean yield for this combination, is also a high negative value but it does not reach 0.05 significance level.

Differences between budded and unbudded members of pairs of twinned seedlings. It will be seen in *Table 21* that in only three cases is the yield of the budded members established as being significantly greater than the yield of the corresponding unbudded twins (PB 186 on Pil A44, Pil B84 on Pil A44 and on PB 20). In one case the yield of the unbudded twins (PB 24 seedlings) exceeds the yield of the budded twins (PB 186 scion, PB 24 seedling stock).

For the girth increment over the same period 1947 – 54, only two differences are established as significant. The buddings of PB 186 on PB 24 had a smaller girth increment than the unbudded twins, while the buddings Pil B84 on PB 20 had a greater girth increment than the corresponding twins.

Differences between buddings (clones). PB 186 and Pil B84 scions are budded on all five seedling families represented in this experiment, but AVROS 50 is budded on only three. This renders a straight-forward analysis of variance unsuitable, and the simplest method of dealing with the situation is by splitting the analysis into three separate parts, according to scion used, and concentrating on differences between stocks but not between scions. Significant stock effects were established when PB 186 was used as scion, but not when Pil B84 or AVROS 50 buddings were used. Among the trees budded with PB 186, the stock Pil A44 showed the highest yield mean (41.4g) which exceeded significantly the mean yield of PB 24 stock (21.9g). These stocks also exhibited the highest and lowest average girths, respectively, in both 1947 and 1954. Stock differences for girth increment were not significant.

Differences between seedling families. In an analysis of variance, the values used were restricted to the unbudded members of twinned seedlings where the corresponding twin had been budded (and included in the previous analysis of variance of buddings). Twins of which neither member had been budded were not considered in this analysis. In no case were significant differences between families established. In contrast to the stock effects with PB 186 scions, there was no indication that Pil A44 was a more vigorous seedling than PB 24, while as regards yield capacity, PB 24 tended to exceed Pil A44.

DISCUSSION

It is possible to criticise this experiment (and the other twinned seedling experiment in Field 4C) on the grounds that:

a. negative correlations could possibly be induced as a result of competition between the adjacent budded and unbudded members of pairs.
b. a positive correlation might be established if pairs were subjected to varying soil or environmental conditions along the length of a double row.

If these factors are operative then one might even find significant correlations between adjacent rows of ordinary (non-twinned) seedlings. In the experimental area, this can be tested to some extent since there do exist such double rows of 'untwinned' seedlings. Although each of the seedlings has in fact been twinned, double rows can be selected which do not consist of *pairs* of twins, and hence can be regarded as unrelated seedlings. Five double rows running east to west and eighteen double rows running north-south (the planting system is square hence rows may be considered in either direction) have been tested for correlation between adjacent pairs, but in no case is significance established with confidence.

One may therefore conclude that the correlations established between twinned seedlings are real effects, and not due entirely to faulty experimental layout. It appears, then, that the correlations between budded and unbudded members of twins provide some evidence of stock influence on scion, though the magnitude of this influence is difficult to assess. It is only established for certain combinations of stock and scion and, even then, only on certain occasions. In general, pairs which have girth correlations, also exhibit yield correlations although there are exceptions to this (the negative correlation for yield per length of tapping cut of PB 186 on SR 9, and the positive correlation for girth increment of Pil B84 on SR 9). With the calculation of a large number of correlation coefficients, a certain number of significant values will occur by chance; perhaps, then, these unsupported correlations of PB 186 on SR 9 and Pil B84 on SR 9 are fortuitous.

The significant differences between budded and unbudded members (*Table 21*) are presumably indicative of the scion influence on the growths and yield of the budded trees.

It is seen that this experiment provides some evidence in favour of stock effects on scions, both from correlations between budded and unbudded members of twins, and from analysis of variance of budded trees only. These two lines of evidence might be expected to give the same verdict, if there was a high correlation between budded and unbudded pairs for all combinations, and if a significant difference had been established between the seedling families. With the observed low proportion of significant correlations, between unbudded and budded pairs, and the similarity of all the seedling families, the two approaches must be regarded as substantially independent. Indeed, considering the lack of differences between seedling families as such, it is a little surprising to find a stock effect established with PB 186 buddings. If this is a true effect, it presumably indicates some sort of interaction between PB 186 scion with certain types of seedling stock. It should

TABLE 21. FIELD 22B. DIFFERENCES FOR MEAN YIELDS IN GRAMS PER TREE PER TAPPING AND GIRTHS IN INCHES BETWEEN (a) BUDDED AND (b) UNBUDDED MEMBERS OF PAIRS OF TWINNED SEEDLINGS

Scion if budded	Illeg. clonal seedling family	Mean yield 1947—54		Girth increment 1947—54	
		(a)-(b)	s.e. of (a)-(b)	(a)-(b)	s.e. of (a)-(b)
PB 186	MAP	0.4	± 3.64	- 0.7	±0.45
	Pil A44	12.3**	± 4.06	- 0.5	±0.37
	SB 9	-14.2	±10.92	- 1.1	±0.79
	PB 24	-22.4*	± 8.57	- 2.6**	±0.64
	PB 20	- 5.5	± 8.01	- 1.1	±0.85
Pil B84	MAP	24.9	±10.61	1.1	±2.13
	Pil A44	14.8*	± 5.50	0.8	±0.73
	SR 9	3.3	±10.70	1.3	±0.77
	PB 24	3.2	± 7.36	1.1	±0.75
	PB 20	16.7**	± 4.44	3.4***	±0.77
AVROS 50	MAP	-11.6	±15.44	1.4	±1.90
	SR 9	- 2.8	± 4.66	0.9	±0.65
	PB 20	-14.2	± 7.93	1.2	±0.98

be pointed, however, that this stock effect has been established only within one scion; the only replication consists of individual trees within rows, and hence, stock effects may be confused with edaphic effects. The correlation coefficients may also be influenced by edaphic and other factors, but, as has been discussed, can be regarded with more confidence, in this particular experimental area.

FIELD 10

METHODS AND MATERIALS

This experiment was set up to study the effects of different heights of budding. The stocks consist of unselected seedlings only; but the proportion of stock to scion varies with the budding height. The experimental layout was systematic, in four blocks each of six rows. With a block, five rows were budded in succession in October 1931 at 2, 12, 24, 36 and 48 in. from the ground; the sixth row was unbudded. The four blocks consisted of trees budded with AVROS 152, SR 9, AVROS 50 and PB 186 respectively. At the time of cutting back the buddings, the unbudded trees were pollarded at 48 in. from the ground. The tapping history of the experiment is given below:

First panel opened in Jan. 1938 at 24 in.
Second panel opened in (?) at 24 in.
Third panel (first renewal) opened in Feb. 1947 at 24 in.
Fourth panel opened in June 1949 at 40 in.
Fifth panel opened in July 1953 at 44 in.
Sixth panel opened in April 1957 at 44 in.

RESULTS

Growth

Most of the girth records exist only as summaries which are not amenable to statistical analysis. *Table 22* shows the mean girth values for 1945 and 1957. It is evident that there are appreciable differences between the clonal buddings, and that, as a group, the buddings are considerably less vigorous than the unbudded seedlings. It is difficult to trace any effect on girth which can be attributed to height of budding. In 1945, trees budded at 48 in. have the highest mean girth, but in 1957 these have the smallest girths. The numbers of trees in each group, however, probably differs from 1945 to 1957, and too much weight should not be given to small changes in relative values.

Yield

The mean yields per tree per tapping are shown in *Table 23*. Figures above the dotted line indicate the yields above the stock-scion union, whilst figures below the line represent stock yields. This can, of course, only be shown approximately.

TABLE 22. FIELD 10. MEAN GIRTHS IN CM

Measurements taken at 50 in. from the ground

Height of budding, in.	November 1945					May 1957				
	AVROS 50	PB 186	AVROS 152	SR 9	Mean	AVROS 50	PB 186	AVROS 152	SR 9	Mean
2	81.9	83.5	73.9	59.4	74.7	103.3	98.6	89.9	78.6	92.6
12	82.9	80.5	70.8	61.0	73.8	102.8	97.3	88.9	75.1	91.0
24	83.7	79.3	71.6	67.9	75.6	100.7	95.2	88.3	84.6	92.2
36	82.5	77.7	70.4	69.3	75.0	104.6	92.5	85.0	86.3	92.1
48	83.9	81.4	75.5	64.5	76.3	97.3	95.6	89.5	72.9	88.8
Mean	83.0	80.5	72.4	64.4		101.7	95.8	88.3	79.5	
Unbudded seedlings	98.6	99.8	110.8	109.6	104.7	123.3	123.1	134.7	136.2	129.3

TABLE 23. FIELD 10. MEAN ANNUAL YIELDS IN GRAMS PER TREE PER TAPPING

The yield means for any clone above the dotted line are scion yields and those below are stock yields

Height of budding in inches		1938	1939	Mar. to Dec. 1947	Jan. to Dec. 1948	June to Dec. 1949	Jan. to Dec. 1950	Jan. to Dec. 1951	Jan. to Dec. 1952	Jan. to June 1953	July to Dec. 1953	Jan. to Dec. 1954	Jan. to Dec. 1955	Jan. to Dec. 1956	Jan. to March 1957
AVROS 152	2	17.3	19.9	59.4	46.2	38.3	41.5	37.5	38.1	38.8	26.2	31.2	29.0	30.4	36.2
	12	13.3	16.2	57.5	51.2	35.3	41.5	36.9	33.6	37.3	25.6	28.1	27.4	27.8	32.3
	24	14.3	24.7	73.9	62.4	42.2	44.7	41.7	46.9	49.9	44.5	40.6	31.0	29.5	39.0
	36	11.4	17.2	43.6	44.2	33.4	32.5	30.6	39.3	42.8	28.2	24.6	17.3	19.5	33.9
	48	11.6	17.4	45.1	49.5	27.1	28.0	33.2	36.3	41.2	18.2	17.4	17.4	20.2	36.6
SR 9	2	12.2	19.9	54.3	43.5	50.4	32.6	29.5	34.7	35.8	23.2	16.7	17.2	20.9	22.4
	12	11.8	17.3	47.3	34.6	42.7	30.0	26.3	29.9	33.3	22.0	17.5	15.6	19.4	30.0
	24	10.8	17.1	37.5	33.4	51.7	37.2	31.3	34.0	33.1	34.3	30.3	22.6	19.8	26.9
	36	9.6	15.3	41.3	43.1	52.5	39.2	33.8	33.6	41.0	27.1	19.5	20.8	22.9	34.0
	48	8.0	13.2	25.0	28.0	18.7	17.4	19.1	26.5	32.9	16.4	9.6	10.0	12.1	21.0
AVROS 50	2	12.8	23.5	48.3	48.8	37.9	39.7	46.1	61.2	62.8	22.1	26.1	32.4	40.2	40.6
	12	10.5	18.9	43.5	44.2	32.8	35.0	39.4	48.6	56.9	23.1	22.7	25.2	33.3	37.3
	24	9.8	19.5	48.5	43.8	30.6	30.4	34.8	51.1	49.0	21.8	19.4	20.0	27.9	31.0
	36	9.2	16.4	48.5	45.9	35.0	34.6	44.7	51.7	51.7	24.0	23.0	28.8	35.2	41.1
	48	9.7	18.2	42.6	45.3	27.0	26.9	44.2	53.1	55.2	22.3	23.1	24.3	33.2	38.9
PB 186	2	15.2	21.8	78.5	71.1	86.9	72.8	69.5	69.1	56.1	45.7	36.5	39.0	42.8	45.7
	12	14.2	23.7	61.7	52.2	74.1	56.2	49.9	44.5	37.8	41.5	37.7	34.0	35.1	35.4
	24	11.3	19.6	47.0	46.6	80.5	58.0	55.0	46.0	44.6	45.7	41.0	29.0	29.0	39.7
	36	9.3	15.9	36.5	41.5	60.8	37.9	32.4	42.5	39.2	38.1	30.2	20.8	26.8	39.3
	48	9.4	16.4	40.7	47.1	40.7	27.8	40.0	47.9	47.2	31.1	18.6	21.2	30.3	36.0
s.e. approximation from the 5 rows of seedlings		—	—	—	—	± 8.9	±11.4	± 6.9	± 4.2	± 3.0	± 3.2	± 7.5	± 4.7	± 5.5	± 4.4
Seedlings (pollarded at 48 in.)		12.7	20.9	56.0	53.5	36.7	36.6	45.5	49.9	49.9	23.9	27.4	28.2	35.4	40.9
Average height (in.) of tapping cut above ground		20.0	11.9	19.4	9.3	37.2	30.2	21.5	11.8	3.8	37.5	31.1	20.6	10.2	3.9

Owing to the design of the experiment, statistical analysis of the data meets many difficulties, and can only be carried out as an approximation.

The standard error of a single row mean may be obtained as an approximation from the variability of the five rows of seedlings. For any particular clone the comparison of mean yields shows that variation in distance of the tapping cut from the union has no significant effect on the yields obtained from the scion. (The height of the tapping cut above ground is the same for all rows in a particular year, and hence different heights of budding lead to different distances of tapping cut from the union). Similarly, the mean yields obtained from the stock at various distances below the union are also comparable. The yield obtained from the scion, however, exceeds that obtained from the stock. This applies to all four clones.

The yields from the rows of trees (different heights of budding) may be averaged to obtain the mean yield of the scion and also the mean yield of the stock for each clone (*Table 24*). An analysis of variance was carried out by assuming that the yields of the scions and stocks from the four clones are independently obtained in all the years. This is, of course, not completely valid, but allows some estimate of variability to be made.

TABLE 24. FIELD 10. MEAN YIELDS IN GRAMS PER TREE PER TAPPING FOR EACH BUDDING WHEN TAPPED ON THE STOCK AND ON THE SCION

Years	PB 186		AVROS 50		AVROS 152		SR 9		Seedlings
	Scion	Stock	Scion	Stock	Scion	Stock	Scion	Stock	
June to Dec. 1949	75.6	40.7	34.1	27.0	37.3	27.1	49.3	18.7	36.7
Jan. to Dec. 1950	62.3	32.8	35.0	30.8	42.6	30.2	33.3	28.3	36.6
Jan. to Dec. 1951	59.7	42.5	42.8	41.2	37.2	35.2	27.9	28.1	45.5
Jan. to Dec. 1952	69.1	45.2	61.2	51.1	38.1	39.0	34.7	31.0	49.9
Jan. to June 1953	56.1	42.2	62.8	53.2	38.8	42.8	35.8	35.1	49.9
July to Dec. 1953	42.3	31.1	22.8	22.3	31.1	18.2	26.6	16.4	23.9
Jan. to Dec. 1954	38.4	24.4	22.7	23.0	33.3	21.0	21.5	14.6	27.4
Jan. to Dec. 1955	36.5	23.7	28.8	24.4	28.2	21.9	16.4	17.8	28.2
Jan. to Dec. 1956	42.8	30.3	40.2	32.4	30.4	24.2	20.9	18.6	35.4
Jan. to Mar. 1957	45.7	37.6	40.6	37.1	36.2	35.4	22.4	28.0	40.9
Mean	52.9	35.0	39.1	34.2	35.3	29.5	28.9	23.7	37.4

TABLE 25. FIELD 10. MEAN YIELDS IN GRAMS PER TREE PER TAPPING WHEN TAPPING ON SCION AND ON STOCK FOR THE PERIOD 1949 - 1957

Clones	Scion	Stock	Mean yield
PB 186	52.9	35.0	44.0
AVROS 50	39.1	34.2	36.7
AVROS 152	35.3	29.5	32.4
SR 9	28.9	23.7	26.3
Seedlings		37.4	

Table 25 shows the mean yields over the period 1949 – 1957.

In the case of clone SR 9, the scion yield (28.9g) and the stock yield (23.7g) are significantly inferior to the seedling yield (37.4g). For clones AVROS 152 and PB 186 the superiority of scion yield over stock yield seems to be established.

In the absence of a scion (or block) influence, all the stocks would yield similarly to the seedlings. The stock yield under SR 9 (23.7g) is the lowest, and is significantly lower than the stock yield under AVROS 152 (29.5g). The stocks under both these clones SR 9 and AVROS 152 are associated with a markedly smaller yield than the unbudded seedlings. Although the stock yield means for AVROS 50 (34.2g) and PB 186 (35.0g) are smaller than the seedling yields, the significance of this is not established.

Consideration of scion yields reveals that AVROS 152 and AVROS 50 are similar to the seedling, but that PB 186 (52.9g) yields significantly more, and SR 9 (28.9g) yields significantly less.

The data may also be studied by a consideration of regression. This is most easily done by expressing the scion yield and stock yield as percentages of the seedling yield in each year, and assuming that these percentages are independent of year effects.

The correlation coefficient between the stock/seedling percentages and the scion/seedling percentages for clones AVROS 50 (0.803**) and PB 186 (0.723*) reach significance level. In these cases, it can be shown that the relationship may be represented by a straight line passing through the origin. Regression equations of this form were, therefore, fitted for all clones:

$$\left.\begin{array}{ll} \text{AVROS 152} & y = 1.2437\ x \\ \text{SR 9} & y = 1.2290\ x \\ \text{AVROS 50} & y = 1.1345\ x \\ \text{PB 186} & y = 1.5163\ x \end{array}\right\} \quad (1)$$

where y denotes scion yield as a percentage of seedling yield and x denotes stock yield as a percentage of seedling yield.

All these regression equations are highly significant. In an analysis of regression, it was shown that the four regression coefficients differ significantly among themselves. Three clones AVROS 152, SR 9 and AVROS 50 may be grouped together to give one regression equation

$$y = 1.1916\ x \quad (2)$$
$$(\pm 0.0502)$$

while PB 186 retains the original equation

$$y = 1.5163\ x \quad (3)$$
$$(\pm 0.0709)$$

In the regression equations (2) and (3) it is established that the coefficients are significantly greater than unity. Hence, scion yield exceeds significantly the stock yield for all clones.

DISCUSSION

Within the limits of the analysis, it appears well established that the yield above the union is greater than the yield below the union. It is shown, nevertheless, that the scion has a notable influence on the stock yield.

The poorest yielding trees (SR 9) have also the lowest mean girth. On the other hand, the highest yielding trees (PB 186) are not associated with the highest girth values, though they are evidently fairly vigorous.

The height of budding appears to have little effect on the growth of the trees, although its influence on yield is apparent. This is a little surprising in view of the fact that (a) more of the original stock is left intact after budding at 48 in. than at 2 in., and (b) that trees tapped mainly on the stock (i.e. those budded at the greatest height) produce less latex than those tapped mainly on the scion. Hence, with more initial reserves, and less drain upon resources, one might expect the 48 in. buddings to be the most vigorous. This is not shown, however.

GENERAL DISCUSSION

Before considering further the results of the various experiments reported in this paper, it should be emphasised again that the stocks consist of illegitimate seedlings. This implies that seed from a given mother clone will vary according to the neighbouring clones, and will even vary with the time of season in which the seeds were harvested. Hence, although Pil B84 and Tjir 1 are both named as stocks in three experiments (Fields 28 and 29, Field 43 and Estate) they are only nominally the same in each case, since, while the mother clone remains constant, the male parent varies in an unknown fashion.

In Fields 28 and 29, Pil B84 seedling stocks are associated with significantly better yields and faster growth during tapping than Tjir 1 seedling stocks. There is some suggestion that Pil B84 scions are best on Pil B84 seedlings, and that Tjir 1 scions are worst on Tjir 1 seedlings. In the estate experiment and in Field 43 no significant differences between Tjir 1 and Pil B84 seedling stocks are found nor is there any indication of interaction. In Field 43, Tjir 1 stocks have slightly larger girths than Pil B84, though Pil B84 yields somewhat more than Tjir 1 stocks. In the estate experiment Tjir 1 is associated with a very slightly larger girth and yield than Pil B84 (when averaged over the true clonal scions).

Three of the seedling stocks in Field 43, Lecointe, Entruncamento and Brazil Import, came from Bahau Estate (or Ritchie's Land as it then was) where the mother clones were grown in a complex pattern allowing free crossing with each other and with AVROS 163, *H. guanensis*, *H. spruceana*, Black Brazilian and other clones. It is therefore likely that there was a thorough genetical mixing, with the seedling families differing consistently in little but the markings on the seed coat (and possibly seed size). The name Lecointe refers to the owner of an estate, Entruncamento to the place of origin in Brazil.

With temperate tree crops, it has been shown that the root-stock normally exerts a greater influence on the budded tree than does the scion (Rogers and Beakbane, 1957). At first sight this appears to be at variance with the results obtained with rubber trees, but it should be noted that the differences in size between the unbudded clonal rootstocks used in experiments with apple trees were very much greater than the differences between the means of the various families of rubber seedlings used in the experiments reported here. Hence, even if the rubber rootstocks exerted very considerable control on the growth of the budded trees, differences between stocks would still be difficult to establish, since they are likely to be less than the differences between the corresponding unbudded seedling families.

With fully compatible trees the rate of growth of the two-component tree might be expected to be the resultant of the growth rates of the two separate components growing in isolation (c.f. Vyvyan (1955) on apple trees). If, in any one experiment, the different seedling stocks have similar intrinsic rates of growth (i.e. when not budded) then one is unlikely to find 'stock effects' on growth showing up in the budded trees. It is instructive then, to compare the girths of the unbudded seedling families in Fields 22B (*Table 19*) and Fields 28 and 29 (*Table 4*), and in the estate experiment (*Table 11*). It will be seen that in these three cases there is no very marked difference between the seedling families; not

only is there little difference between the means, but within each family there is very considerable variation. This being so, it is somewhat surprising that significant stock effects on girth should be established in Fields 28 and 29 (Tjir 1 significantly less vigorous than any other), the estate experiment, and in Field 22B (when PB 186 is the scion). As mentioned previously, the stock effects on girth established in the estate experiment are very small and may well be an artifact. In Field 22B, lack of randomisation lays the results open to doubt owing to the possibility of environmental gradients affecting performance of the trees. In Fields 28 and 29, however, the experimental layout is better (though still not thoroughly randomised) and here there seems to be some indication of interaction between a particular scion (Tjir 1) with a particular seedling family (also Tjir 1). If this is a true result, it suggests that certain stocks may exert an effect by virtue of factors other than simple vigour of growth.

If the growth rate of the budded tree is merely some constant product of the vigour of the scion and the vigour of the stock, (midway between the two, for example) then one would expect to find a close correlation (linear regression) between the sizes of budded and unbudded members of pairs of twinned seedlings; this conclusion is not affected by the relative magnitudes of stock and of scion effects on each other, but would be true whether stock or scion were the dominant partner. It follows that, provided girth measurements adequately represent the size of the tree, significant correlations for girth values of budded, and unbudded twins would be expected. In Field 22B, six combinations of stock and scion show no indication of girth correlation with their respective unbudded twins, while only two combinations have consistently significant values for girth in 1947 and 1954, and for girth increment in the period 1947 – 54.

The comparative variety of such established correlations for girths may therefore indicate that factors other than intrinsic vigour of stock and scion play a part in determining the size of the budded tree. In this direction, one may only speculate on possible biochemical and anatomical disharmonies between the clonal scion and the genetically variable seedling stocks.

As regards yield, the situation is even more complex than with girths. The results for Field 43 show that the stock may have an effect on the yield of the scion independently of its effect on size; this yield effect is seen most clearly when the tapping cut is low on the trunk. In Field 10, it was shown that tapping on the stock may produce a lower yield than tapping on the scion. In the twinned seedling experiments, yield correlations usually appear to be associated with girth correlations, but there are exceptions; Pil B84 on MAP and AVROS 50 on MAP, both show occasional significant yield correlations but no sign of girth correlations. These exceptions can perhaps be largely accounted for by considering the position of the tapping cut on the tree at the time the correlations are found, in 1952 and 1948; in each case the tapping panel is near the base of the tree. It is difficult, however, to explain the significant yield correlation of Pil B84 on MAP in 1947, on these lines.

In Field 4C, significant correlations of budded with unbudded twins for yield per inch of tapping cut are found only in 1940, 1953 and 1954. In both 1940 and 1954 the tapping cut was on or near the stock.

The experiment in Field 43 includes one seedling stock which has been the subject of some controversy, namely, *H. spruceana*. In the early experiments in Sumatra, SCHMOLE (1941) reported that *H. spruceana* seedling stocks were highly superior to unselected *H. brasiliensis* stocks. This experiment has been criticised by Maas and Ostendorf, quoted by PAARDEKOOPER (1954) who published the results of a trial in Java which also included *H. spruceana* stocks. In this case it was shown that the *spruceana* stocks had a clearly unfavourable effect on the yield of all clones used. This is in agreement with the result of the experiment in Field 43. In a further trial at the R.R.I. Experiment Station (Field

48C), not reported in detail here, no significant differences in yield between *H. spruceana* and unselected *brasiliensis* stocks have been established after three years of tapping, though it should be noted that the tapping cut is still fairly high on the panel; PB 86, RRIM 501, GT 1 and Tjir 1 were the scions employed. It seems very likely that the performance of the *H. spruceana* stocks depends largely on the origin of the seed, the *spruceana* mother clone and the source of the pollen effecting the fertilisation. In Schmole's experiment, as well as in Field 43, the '*spruceana*' seedling stocks were almost certainly the result of crossing with *brasiliensis* pollen. If the hybrid seed forms a particularly vigorous stock it may partially offset its low intrinsic yield capacity; this is probably the explanation of Schmole's experimental result.

From a practical point of view the seven experiments reported in this paper do not permit any strong recommendations concerning the use of seedling families as stocks. Pil B84 seems to be one of the better mother clones, and AVROS 163 is probably equally good but the presence of an unfavourable pollinator clone might seriously affect the performance of the illegitimate families. Tjir 1 illegitimate seedlings appear to be good stocks on occasion, but, in some circumstances they appear to react unfavourably with Tjir 1 clonal scions; this reaction may well depend on the pollinating clone.

Conclusions which may be drawn from these experiments are as follows:

a. Scion effects on budded trees in respect of both girth and yield are well established in several experiments (Fields 1A, 28 and 29, and the estate experiment); stock effects are established with much less certainty and appear to be of a smaller magnitude. This may be, at least partly, attributed to the small differences in vigour of growth between the seedling families used as stocks.

b. It appears likely, from the twinned seedling experiments and from the experiment in Fields 28 and 29, that certain stocks may be especially favourable (or unfavourable) for certain scions, i.e., there can be an interaction between stocks and scions.

c. Stocks may exert an influence on the yield of the budded tree independently of any effect on growth.

d. With trees budded near ground level, tapping low on the trunk results in a higher yield than tapping higher up the trunk; this is accentuated with high yielding stock material such as AVROS 163 or Pil B84 (Field 43).

e. With high yielding scions budded on unselected stocks, tapping below the union results in a lower yield than tapping above it (Field 10). Presumably this result could be reversed by using a low yielding clone on the best seedling stocks.

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